ROADS AND PAVEMENTS

IN

FRANCE.

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PREFACE.

THIS contribution to the literature of Road Making will, it is believed, be of service to all who are interested in the improvement of our highways both in the city and in the country. It is partly the result of personal observation by the writer, but is mainly a compilation from the standard publications of Monsieur A. Debauve, Ingénieur en Chef des Ponts et Chaussées in charge of the Département de l'Oise, and from the official documents of the French Government.

The writer desires to express his obligations to the several friends who have aided him in various ways, and more especially to M. A. Debauve, Ingénieur en Chef des Ponts et Chaussées; M. F. Guillain, Inspecteur Général des Ponts et Chaussées, Conseiller d'État; M. Boreux, Ingénieur en Chef des Ponts et Chaussées et de la Voirie de Paris; and Prof. C. Frank Allen, Massachusetts Institute of Technology, for courteous assistance and valuable material.

ALFRED PERKINS ROCKWELL.

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ROADS AND PAVEMENTS IN FRANCE.

HISTORICAL.

THE history of roads in Europe is interesting as being in short the history of civilization. The condition of the means of communication reflects fairly well the general state of society during the successive centuries.

The Romans, as every one knows, were the first great road-builders. By means of their wonderful system of permanent highways, reaching from Rome to every part of the vast empire, and over which their great armies moved, they held in subjection every province and planted their civilization in the heart of each conquered people. With the breaking up of the empire and the invasion of the barbarians came a great change in the conditions and requirements. The necessity which created these great highways ceased in a measure, and the roads were no longer maintained. Such solid work was not indeed destroyed, but in time it simply deteriorated from neglect.

Later Charlemagne did much to restore them to good order, as he, like the Romans, had large armies to move rapidly over great distances.

Later again, under his weaker successors and still more under the feudal system which followed, the roads were almost entirely neglected, and their deterioration was well-nigh complete. The feudal lords in some cases, it is true, maintained them within their several domains, but more often neglected them, and in fact sometimes actually destroyed them, the better to defend their territories against more powerful neighbors. Moreover the state of society in the Middle Ages did not demand good roads. Carriages for personal travel were but little used, as the great lords and ladies travelled mostly in the saddle. General commerce counted for nothing, and what little survived on land was hindered or destroyed by arbitrary exactions and continual petty wars.

The recovery from this deplorable condition was slow in coming. Not only the roads of the country but even the streets of important towns were often impassable at certain seasons. Even in the twelfth century the only main roads in France were those originally built by the Romans. Louis XIV. in the latter part of that century made, it is true, some good roads in the vicinity of Paris, but it was not till about 1775 that a genuine revival took place. Under Napoleon I. road-building, as it is understood to-day, had a great development both in France and in the countries which he conquered. The famous road over the Simplon Pass from Switzerland into Italy was made by his orders in 1800–6. From this time on the progress has been great and continuous; so that to-day all Europe, with the exception of Russia, is covered by wagon-roads, which are adapted to the requirements of each district, and are models of durability and excellence.

A PERFECT WAGON-ROAD

should have an easy grade, a surface hard, smooth, even, and slightly convex to insure prompt and perfect drainage, be nearly or quite impermeable to water, and at all seasons be, as nearly as practicable, free from mud and dust.

Such roads are to be found in the best of our city parks. They are rather costly to build, and are kept in perfect order only by constant care. Such roads are, however, common enough in all parts of Europe, not simply as park roads and for pleasure driving merely, but as the high-roads of general travel, running for hundreds of miles throughout the country, connecting cities, towns, and villages, and giving easy communication for general traffic. Long experience and careful study have convinced the various governments that the well-being and prosperity of all parts of the country, of rich and poor alike, depend in great measure upon a well-considered system of highways, built with great care and maintained always in good order. The economy to each community of a good wagon-road, whatever may be its cost, is no longer an open question in countries and districts where small economies of all kinds are matters of anxious consideration. Thoroughness of construction is a characteristic feature, and a grade once established and a road once built need rarely be changed.

The saving in wear and tear of wagon and harness and the increased loads a horse can haul are perfectly well understood and recognized by all who have produce or merchandise to carry to market. Two hundred years ago good roads, if any existed then, were built for the convenience and pleasure of the king and his nobles; to-day they are built to serve the interests of general industry. The presence or absence of such means of communication and the condition in which they are kept are justly regarded in Europe as a fair index of the degree of civilization of the community or country.

In our own country the increased demand, within the last few years, for improvement of the highways, which has more recently taken shape in state legislation, is gratifying evidence of a growing interest in the subject, that is likely to lead to good results.

With the hope of aiding the cause of highway improvement the writer contributes this little book, mainly made up of an account of stone roads in France, their mode of construction and maintenance, and embodying to some extent the results of experience of some of the best French engineers. It is chiefly compiled from the published books of Monsieur

A. Debauve,* Ingénieur en Chef des Ponts et Chaussées, in charge of the Department of Oise, and from the official reports of the Minister of Public Works.

As a matter of course, the methods and practice of one country are rarely applicable in all their details to another country, where many of the conditions of population, climate, etc., are quite different. At the same time all experience teaches something, either to imitate, modify, or avoid; and it seems probable that we may learn something of value from the conclusions reached by the highly educated and able engineers who, one after another, have for more than a hundred years had charge of the national roads of France. The best and most economical method of construction and maintenance, under existing conditions of climate and population, has been their constant aim; and the excellent roads of France to-day are the best evidence of the faithfulness and skill of the French engineers in charge.

The improvement of our own roads, which so many of us earnestly desire, cannot be too carefully and thoroughly studied. The best and most economical method or methods of construction and maintenance, the adaptation to the requirements of each region and of each special case, with due regard to the amount of present and future travel and to the money that may

* Manuel de l'ingénieur des Ponts et Chaussées; Paris, 1873. Instruction Générale pour le service courant; Paris, 1894. Dictionnaire Administratif des Travaux Publics; Paris, 1892.

be properly spent for the purpose, the nature of the material to be used, the determination of grade and width, and, above all, the permanent nature of the work, are fundamental points to be carefully weighed before decision. No detail is unimportant. It is hoped that, on this subject at least, the period of temporary makeshifts is over, so that work done, however incomplete, may not need to be undone, but be the basis of further possible improvement in the future.

We are no longer satisfied with the common dirt road, which served a useful purpose when no better was to be had; and yet in some districts, where population is sparse, it will still be the only practicable one. In many cases it may doubtless be materially improved at no greater outlay of money than the present annual cost, and with much indirect advantage to those using it. In its worst form and under the most unfavorable conditions of climate and soil it is barely endurable during eight or nine months, and is often nearly impassable for two or three months of the year. Its like may be found in certain parts of Russia, where the roads give easy communication only during four months of summer and four of winter.

Between the two wide extremes of the perfect park road before mentioned and the worst mud road lie all possible degrees of goodness and badness.

Assuming, then, that the object is to get the best practicable road under the circumstances in each case, the various points to be considered, whether in building a new road upon a new line, or in improving one already built, may be conveniently grouped under the following heads, viz.:

1. Grade.
2. Material.
3. Mode of Construction.
4. Maintenance.

A highway is a permanent work, and the laying out and building of it is a matter of corresponding importance. The problem should be studied with an accurate survey of the line of the road in hand, accompanied by full specifications and close estimates of the amount of each part and kind of work to be done. Such preparatory work is the only safe basis for determining intelligently the several points at issue. Without it the whole thing is a matter of guesswork.

Accuracy is always economical and guesswork costly and wasteful. A shrewd contractor's guess allows a very liberal margin to cover the unknown. It is the duty of the engineer to define accurately the conditions of the problem and eliminate the uncertainties, and if he is a competent one his services are many times worth his cost.

I. GRADE.

The advantages of an easy grade are too obvious for discussion.

The standard adopted in France is:

National roads, not exceeding		3 in 100
Department "	" "	4 in 100
Subordinate "	" "	5 in 100

This standard is adhered to where practicable, but obviously the rule is not absolute, and is very often exceeded of necessity, especially in a mountainous district, or where the travel is too light to justify an excessive expenditure to keep the grade down to standard.

A horse may be easily driven at a trot on a grade of 3 in 100, whatever its length, and on a grade of 4 in 100 for a short distance, but if the grade is steeper than this he will naturally go at a walk.

Steep grades limit so greatly the load a horse can haul that, if the road is much used by heavily loaded wagons, the greater cost of the longer line, with easy grade, would often be sound economy in the long-run. In fact, it may often happen that the extra cost is by no means serious, and is of small account, in view of the manifest advantages of the better grade. This point should be most carefully studied in the laying out of a new road. The errors of the past are hard to correct.

The idea prevailed at one time, and unhappily was largely acted on, that the main road between important towns—such, for instance, as the old stage routes—should be a straight line, going up and down hill across the country, without regard to the inequalities of the surface. It may at first have been the most direct pathway or horse-track through the otherwise trackless forest, or it may be a legacy of the old Roman times, when the marching of armies was more important than the movement of heavy loads of produce or merchandise. Whatever its origin, the result to-day is, in too many cases, a road with grades that ought to be modified to satisfy modern requirements. Moreover, the straight line, with its steep ascents and descents, is sometimes not even the shortest in actual distance. But even if it be somewhat the shortest, this, its only advantage, may be more than counterbalanced by other considerations. It not unfrequently is the case that a road winding along valleys and *around* the hills is but 1/5 or 1/6 longer than the direct road over the hills. It must also be remembered that an ascent of 5 in 100 calls for an expenditure of force in hauling, *in a given time*, three times as great as if the road were level; or, if the force expended be the same in both cases, then the time of ascent must be three times as long. Yet a grade of 5 in 100 is considered moderate. The difference is still more striking when the grade is 6, 7, or 10 in 100. In fact, all the arguments, the saving of time, the greater loads that can be hauled, and the less expense of keeping in order, are in favor of a line somewhat longer, but nearly level or slightly undulating, as against the direct line over the hills. The straight line is only an abstract idea of no practical utility.

In many cases, however, there is evidently no choice. It may be necessary to cross a range of hills that are not cut by cross valleys, or the road must be carried over the hill to serve the village on the summit, though even here the height should be surmounted by a winding road with easy grade. But where there is no such determining reason every consideration of economy and public convenience favors the longer line, winding with easy grades along the valley.

An absolutely uniform grade is theoretically the best for hauling, and on railways with steam or electric power it is practically the best, but where horses are used it is far from having the same advantages. Experience seems to show that nothing fatigues a horse so much as a steady pull up a long uniform grade, and that it is often better to vary the strain on the collar by varying the grades. An alternation of slightly ascending and descending grades is preferable to a dead level, not only for the comfort of the horse, but to secure more perfect drainage of the roadway.

II. MATERIAL.

A *clay soil* gives, perhaps, the worst possible road. During a part of the year, when hard, dry, and smooth, the road seems to answer all the essential requirements, but at some seasons it becomes well-nigh impassable for heavily loaded wagons, and is endurable only when, in a sparsely settled region, the community is too poor to afford the cost of better material brought from a distance. The wooden plank-road, adopted in some parts of the West, was a temporary remedy.

Gravel, under certain conditions and when properly used, answers most of the requirements. All which passes under that name, however, is not equally good. For this purpose it should be as free as possible from clay or marl. In regions where it is abundant it is the material naturally used on all country roads, and nothing will replace it till the increase of population, and consequent increase of use, demand a harder and more durable substitute. A gravel road, like everything else, wears out with use, and, in proportion to the amount of travel, requires more or less frequent renewal with *fresh* material. What has been washed off of it into the ditches should never be scraped back on to its surface.

Broken Stone.

This, beyond question, is the best material. Its cost, however, and the care needed for its proper use limit its general adoption to cases where the amount of travel or other special reason justifies a large expenditure of money.

The choice of the kind of rock to be used is important, though in the majority of cases there is practically but little choice. and the rock nearest at hand must be the one used. The hardest and toughest is the best, since roads made of it are more durable, have a harder surface, diminish the resistance to be overcome in hauling, and with an equal amount of travel are less worn, and consequently are more easily and cheaply kept in order.

The choice most frequently lies between an inferior and cheaper rock close at hand, and a better but more costly one brought from a distance. The better and more expensive rock may prove more economical in the long-run, but the cost and conditions in each case must decide the question. The relative quality of the different rocks available—that is, their hardness, toughness, mode of fracture, and fitness for this special purpose—should be first determined by careful tests in each instance without regard to the *name* of the rock, since rocks having the same general name vary very materially in fitness for this use. The better the quality, the less proportionally is the wear, and the wear is regarded as being in proportion to the amount of travel.

Hardness, though most valuable, is not the only thing, for the rock may be hard and tough and resistant, or it may be hard and brittle and splinter easily under the blows of heavy wheels, so that a somewhat softer but tougher rock may prove in practice the more advantageous.

In France a scale of quality from 0 to 20 has been adopted, in which 20 stands for the best.

* Following is a list of most of the varieties of rock used, with the quality of each kind:

			Quality.
Porphyry.............	varying	from	10 to 20
Trap.................	"	"	16 " 20
Basalt...............	"	"	10 " 19
Quartzite............	"	"	11 " 19
Grès quartzose........	"	"	10 " 20
Flint.................	"	"	8 " 19
Quartz................	"	"	10 " 18
Serpentine............	"	"	12 " 18
Melaphyr	"	"	16 " 17
Diorite...............	"	"	13 " 17
Limestone.............	"	"	5 " 17
Gneiss................	"	"	5 " 17
Granite...............	"	"	8 " 16
Millstone grit........	"	"	6 " 16
Amphibolite...........	"	"	11 " 15
Schist................	"	"	3 " 15
Mica schist	"	"	6 " 13
Pudding-stone.........	"	"	4 " 8

The wide variation in the quality of rocks classed under the same name is noteworthy and instructive, and the list is given here mainly to show it, for the fact is that flint and limestone are by far the most commonly used.

The quality taken in connection with the cost of the broken stone delivered on the road must evidently determine the economy of using one rock or another.

* Ministère des Travaux Publics. Routes Nationales, 1893.

Thus it would probably be economy to use trap of quality 20 in preference to limestone of quality 8, even if the cost of the former be double that of the latter.

In the year 1893 there were used in the repair of the 22,000 miles of "Routes Nationales" about 1,702,000 cubic yards of stone. The general average quality was 10.85. One fifth of the whole was of quality 15 to 20, and one fourth was of quality 7 and below. Evidently it was thought better economy to use the inferior and cheaper stone near at hand rather than the better and more costly from a distance.

As an instance, take the Department of Oise. They use—

1. *Flints*, collected from the fields and quarries, the quality of which varies between 8 and 13, averaging 11.

2. *Limestone* from quarries; quality, 8 to 9.

3. *Millstone grit*, compact; quality, 13 and upwards.

4. *Porphyry;* quality 20.

In the year 1893 there were used for repair of 250 miles of road in this Department, as follows:

Kind.	Quality.	Quantity, Cub. Yds.	Cost of Stone per Cub. Yd.	Average.
Limestone	9	425	$0.56 to $1.58	$0.96
Flint.................	11.12	13,653	0.83 to 1.48	1.04
Millstone Grit.........	16.	3,892	1.93 to 2.75	
Porphyry........... .	20.		2.11 to 3.54	2.62
	12.96	17,970		1.47½

The average travel was 227.8 *units* in the 24 hours.

The quantity used was 72 cub. yds. per mile or 31.60 cub. yds. per mile and 100 *units*. (See page 65.)

The stone of best quality and highest price was used on roads in and about the large towns, where the travel is heavy. The flint of medium quality and low price was used on the greater part of the roads.

Preparation of the Material.

The *cleanness* of the stone is important. Soil, loam, and even gravel or sand incorporated in the body of a stone roadway are injurious to its solidity. Other things being equal, the roadway is so much the better the less fine material it contains; hence the need of care to have the stone clean. That broken by the crusher or by hand will naturally be free from foreign matter, but stones gathered in the fields and used unbroken will nearly always have more or less soil or clay adhering to them.

The *size* to which the rock should be broken depends on its hardness and the special use intended. Pieces 3 to 4 inches in diameter are suited for the body of a new road, where a heavy stone roller is used, more especially if the rock is no harder than limestone; but if it be much harder, like trap, the standard size both for new work and repair is 2½ inches in diameter. Where a heavy steam-roller is not used, it may well be 1½ to 2½ inches. Absolute uniformity and regularity of dimensions is practically impossible, desirable as it is;

but any considerable inequality in size is objectionable, as it tends to cause unequal wear, and in time makes the surface rough with protuberances. This is especially true when the harder rock is used. Pieces approximately cubical in shape, with sharp edges, are better compacted under the roller and form a more solid roadway.

III. CONSTRUCTION.

The simplest method of making a common dirt road is evidently to plough a few furrows on each side, where the ditches are to be, and scrape the material toward the centre, rounding it up enough to cause the rainfall to drain off as promptly as possible. This is one degree better than no road at all, and in a new country does well enough when dry, but during part of the year the depth of mud on it depends mainly on the richness or the clayey nature of the soil composing it. The richer the soil the worse the road.

If the soil happens to be gravelly, and a thickness, say of 3 to 4 inches, of gravel be put upon the road, the result is quite different. But even a gravel road often leaves much to be desired. The drainage is almost always defective, no matter how high it may be rounded up in the middle, and in fact the more it is crowned, if the road be narrow, the worse it often becomes; for the inevitable tendency to form a single track along the middle is increased, and the deeper the wheel-tracks the more they hold the water and prevent proper drainage. A very moderate amount of attention might greatly improve such a road. The construction of an ordinary gravel road is shown in Fig. 1. To keep such a road in perfect condition requires considerable care. The frequency of renewal with fresh gravel and the quantity required must depend upon the amount of travel and consequent wear. The

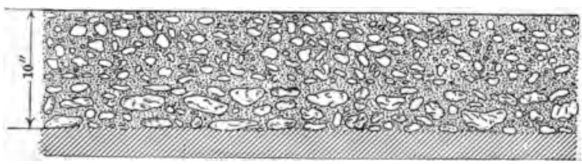

FIG. 1.—GRAVEL ROAD.

vicious method of repair, so commonly used, which consists in scraping every spring from the ditches the fine mud which has been washed off from the road, and in putting it back upon the road tends to ruin what might otherwise be a very tolerable roadway. Repairs should always be made with fresh gravel.

Stone Roads.

All of the methods employed in the building of stone roads have one essential characteristic in common, viz.: The upper layer of the roadway is made up of stone broken into small pieces and compacted so as to form a solid mass. This layer must be built and maintained in such manner that wagon-wheels shall, under no circumstances, cut through it and penetrate the stone foundation, if the road is built with one, or the ground below, if the layer of broken stone rests immediately on the earth.

The old Roman roads were, according to modern ideas, unnecessarily thick and solid. Enduring as they were, the great cost of such thick masses of masonry would not be borne to-day. The modern road has either no stone foundation at all or one of only moderate thickness. In France the tendency has been to do away with the foundation, and to reduce the thickness of the upper layer, making it only so thick as is necessary to give sufficient resistance; in short, to build less costly roadways and to maintain them in proper condition by constant care.

The various methods employed resolve themselves into two general classes: the one, roads *with* stone foundation; the other, roads *without* it. These have been more or less modified by the whim of the engineer, or by unusual requirements in special cases.

Roads with Foundation.

As early as 1764 Trésaguet, a French engineer, introduced great improvements in the mode of construction, which ten years later were generally adopted in France. Such stone roads as there were at that time were 18 feet wide, and had generally a thickness of 18 to 22 inches in the middle and 12 to 16 inches on the edges. Trésaguet considered this thickness excessive, and reduced it to 10 inches, but made it uniform for the whole width of the roadway. The earth was excavated to the requisite depth for the whole width of the proposed roadway, thus forming a broad shallow trench, which was to receive the stone. Under the earlier system the bottom of this trench was horizontal, but Trésaguet gave it the same convexity that the surface of the roadway would have when finished. On this smoothly dressed bed, sloping from the centre to the edges, the first layer of somewhat large stones was carefully laid by hand on their edges, and as compactly as possible; it formed thus a kind of rough pavement. On top of this successive layers of somewhat smaller stones were laid, also by hand, projecting points broken off with a sledge and thoroughly pounded till the mass was solid, care being taken to fill up the spaces between the stones. This constituted the foundation. Finally, the top layer, three inches thick of stone broken to about the size of a walnut, was spread uniformly over the surface. Trésaguet's system, more or less slightly modified, was the one used almost exclusively in France until about 1820, and under it were built all of the roads now classified as "roads with foundation." Of the 22,000 miles of *Routes Nationales* in France, only about 9000 miles, however, are roads with foundation. Some of the roads built under Trésaguet's system had, however, a thickness of 16 to 20 inches, an additional layer of stones, laid flat, being placed at the bottom, and on top of this layer stones on their edge, and so on to the surface as above described. This additional layer was required only when the ground was not thought sufficiently solid.

Telford's System.

This is a modification of Trésaguet's system, introduced into England by Telford, an English engineer, about 1820, and received with much favor. The practical identity in principle of the two systems is such that it is unnecessary to describe in detail the whole construction. From the specifications for building a part of the Holyhead road we may learn Telford's early practice. The bed of the trench is horizontal, and not rounding. The larger stones for the foundation to be placed in the middle of the road are 9 inches deep, and at 9 feet from the centre 5 inches. They are to be placed with their longest edge perpendicular to the axis of the roadway, and their width at the top is in no case to exceed 4 inches. All of the projections of the upper surface are to be broken off, and the interstices between the stones filled with small fragments well rammed in. This foundation is then a rough pavement having a convexity of 1/60. This is to be covered with a layer, 6 inches thick, of hard stone, so broken that the largest piece in its longest dimension can pass through a ring of 2½ inches interior diameter. Four inches of this layer are to be spread first, and after this sublayer has become quite solid and compact by travel the two remaining inches are spread evenly over it. Finally, the whole surface is to be covered with a coating, 1½ inches thick, of good gravel free from earth or clay.

Since that time the Telford method has been more or less modified, but the characteristic foundation of larger unbroken stones, supporting a thinner surface layer of small broken stone, is essentially unchanged.

This method of construction, as often employed, is shown in Fig. 2.

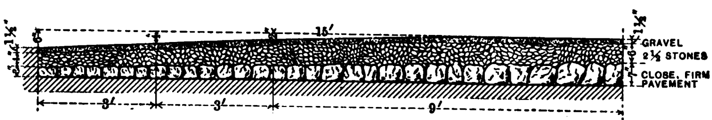

FIG. 2.—TELFORD ROAD.

It will be noticed that the bottom layer of large stones, which forms the foundation, rests upon a horizontal bed of natural earth. The better construction is to give to the surface of this bed the same convexity or crowning as that of the finished road, thereby insuring better subdrainage of any water that may find its way to that surface. The stone layer is consequently of uniform thickness the whole width of the roadway.

The roads built in Essex County, N. J., by Mr. James Owen,* C. E., are examples of this system. The

* Address on Highway Construction in New Jersey. By James Owen, C.E. 1893.

earlier roads he built 12 inches thick, that is, 8 inches of foundation and 4 inches of broken stone. Subsequent experience has led him to recommend for all ordinary highway purposes a total thickness of 8 inches, that is, 5 inches of foundation and 3 inches of stone broken to the size of 1½ to 2 inches in diameter.

A thin layer of loam or clay is sometimes spread on top of the foundation to fill the spaces between the stones and give an even surface to receive the top layer of small stones. After the small stones have been brought to a somewhat even surface under a two-ton roller a thin coating of loam is spread over them.

Other engineers disapprove of the addition of loam or clay into the body of the roadway or upon the surface, believing it to be a positive injury to the solidity of the road. They advocate a heavier roller, as a means of compacting the stone and of making the roadway more enduring.

Roads without Foundation.

These are all made on the Macadam system more or less modified. This system consists essentially in doing away with a stone foundation of any kind, and in replacing the two or three layers of the older system by a single layer 6 to 10 inches thick, rarely less, of small broken stone as nearly as practicable uniform in size, which layer shall be impermeable to water.

The great road over the Simplon Pass from Switzerland into Italy, built by French engineers under the orders of Napoleon I., was perhaps the first road of importance built without a specially laid stone foundation. The perfect solidity of the rocky bed rendered such a foundation unnecessary. The roadway was accordingly composed of small broken stone from bottom to top without distinction of layers.

Macadam in England in 1816 appeared with his method, and made such great improvement in the roads put under his care that his system was generally adopted in England, and for several years had no rival till Telford and the advocates of roads with foundation gained a share of popular favor.

Subsequently Macadam's system was introduced into France, and gave such satisfactory results that it became thoroughly established there, so that for many years it has been used exclusively on all of the public roads. All of Macadam's ideas were not accepted, but the essential principles have been applied in the construction of nearly all the modern French roads.

The ordinary method of construction of a macadam road is shown in Fig. 3.

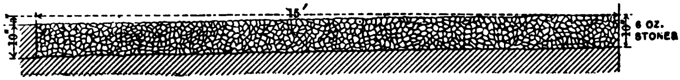

FIG. 3.—MACADAM ROAD.

The thickness of the layer of broken stone is here given as 10 inches. It is sometimes, though rarely, more, and is oftener less, especially where the natural foundation is exceptionally dry and solid. The size of the broken stone is very generally 2½ inches, but in some cases the lower part of the layer may be made of stones 3 to 4 inches in diameter and the upper half 2½ to 1½ inches in diameter.

Thickness.—A stone roadway may be solid without being very thick. The essential condition is that it shall form a compact and impermeable mass, completely protecting the ground below from the effects of moisture. The natural earth, when perfectly dry, will resist sufficiently well the heaviest loads. It is quite possible, using broken stone 2 inches and less in diameter, to make a solid roadway that, when compacted, shall be only four inches thick. There are many old roads still in good condition, which have been found on examination to have a thickness not exceeding four inches. But such a road could hardly be durable except under the most favorable conditions of soil and climate. It might answer, if the ground beneath were hard, gravelly, and naturally dry and the travel light, but in the great majority of cases it would not resist the frosts of many winters. A thickness of less than 6 inches is not advisable; that of 8 inches is much better. This means the thickness of the finished road after the stone, loosely spread, has become compacted and solidified by persistent rolling or travel. Experience seems to show that the harder the stone the less the thickness required.

In this connection the official * report on the present condition of the *Routes Nationales* of France may be of interest.

The 22,000 miles of *Routes Nationales* are periodically examined with great care in order to ascertain the actual thickness of the stone layer, and to determine whether the roadway has been fully maintained by restoring to it annually fresh material to replace that lost by wear, or whether it has been allowed to deteriorate. Tests were accordingly made in 1865, 1874, 1886, and 1891, and they were most thorough.

At intervals of 656 feet (200^m) along the road a trench is cut, at right angles with the axis of the road, from the middle to the outer edge of the stone layer. This trench is about 20 inches ($0^m.50$) wide, and is dug with the pick down to the earth below, or to the stone foundation, if there is one, without penetrating either, and the contents removed. The width and depth of this trench are then accurately measured. A perfect section is thus made of one half of the roadway. These trenches are cut alternately on the right and left sides of the axis of the road, so as to give sections of the whole width without at the same time interfering with travel. The general average of nearly 500,000 such tests, made in 1891, showed a thickness of $5\frac{1}{8}$ inches ($0^m.131$). The average thickness of the

* Ministère des Travaux Publics. Routes Nationales. Sondages des Chaussées en 1891.

layer of broken stone of roads *with* stone foundation was 4¼ inches (0m.107) above the foundation, and on roads *without* foundation 5⅞ inches (0m.148). This general average, however, by no means represents a uniform thickness throughout the country. Thus in different regions, and for reasons that are not apparent, it ranges on roads *without* foundation from 3⅛ in. (0m.079) to 10⅝ in. (0m.270), and on roads *with* foundation from 2½ in. (0m.064) to 8½ in. (0m.218).

The following table shows by percentages the relative number of miles of the different thicknesses:

Thickness of Stone Layer.	Without Foundation. Per cent.	With Foundation. Per cent.	Total Per cent.
Less than 2 inches (0m.05)	6.94	16.80	10.94
Between 2 in. (0m.05) and 4 in. (0m.10)	26.13	38.29	31.06
" 4 " (0m.10) and 6 " (0m.15)	27.58	26.05	26.96
" 6 " (0m.15) and 8 " (0m.20)	20.19	11.43	16.63
" 8 " (0m.20) and 12 " (0m.30)	15.12	6.11	11.47
More than 12 in. (0m.30)	4.04	1.32	2.94
	100.00	100.00	100.00

From which it appears that two fifths of the total length of the *Routes Nationales* have a thickness less than 4 inches, and 4 inches is the limit below which it is thought unsafe to go. One eighth only have a thickness exceeding 8 inches.

A comparison with the tests made in 1886 shows that the general average thickness on the 22,000 miles was only 5/32 inch less in 1891 than in 1886. This seemingly trifling difference, however, represents a net loss of about 730,000 cubic yards of material from the surface of the roads, and would seem to indicate that that amount of broken stone was needed to restore the roads to the condition they were in five years before.

As to what may be the condition, in this respect, of the 300,000 miles of stone road variously classed as *departmental*, *communal*, etc., the writer is unable to say, as there are no official reports published or readily accessible; but it is assumed that they have been built in the same general manner and on the same principles as the *Routes Nationales*. It is certain, however, that many of them lack the perfection which characterizes the latter, and are not maintained with the same care.

Binding Material.

The stone layer, 6 to 9 inches thick, which forms the solid roadway, inevitably contains a certain percentage of fine material intermixed with the broken stone, even when none is intentionally added while the road is being built. This, in an old roadway, is rarely less than 33 per cent, and is often as much as 50 per cent of the whole mass. In the best roads this so-called binding material is formed in part by the crushing of the stones or their grinding one against another under the heavy steam-roller when the road is first built, and in part by subsequent travel.

In some districts the practice has prevailed, and is still adhered to, of mixing a certain percentage of fine gravel as binding material with the broken stone at the outset. In support of this practice it is urged that a good roadway always contains at least 33 per cent of fine material and that it is better to mix this, at the outset, with the stone, rather than let it be formed at the expense of the more costly stone.

This is, however, believed to be a mistake, and the theory on which it rests a false one. Doubtless a road containing 33 per cent of binding material may be a good one, but it would be a better one if it contained less. Some of the best engineers consider the point now well settled, that, *other things being equal, a roadway is so much the better the less fine material it contains.*

It is true that, where no heavy roller can be had, the mixing of a moderate quantity of gravel with the broken stones may seem desirable in order to bind them the more quickly, but it is equally true that this factitious solidity must always be at the expense of the ultimate durability of the road. Hence no binding material should be mixed with the stone, but the latter should be kept perfectly clean and free from all foreign matter whatever. The passage of a 10-ton steam-roller 40 or 50 times over a given point renders all binding material superfluous, and compacts the stone so thoroughly that it becomes a mass nearly as solid as the rock itself.

It is interesting to note that prior to 1830 neither steam nor horse-roller was used, ordinary travel being forced to gradually compact the loose stones. About that year it was tried in England, and a few years later was introduced into France.

When, however, the broken stone has been thoroughly compacted under the heavy roller, and not till then, a layer of screened gravel, free from clay, 1/3 inch thick should be spread over the surface to fill up the small interstices that may still be left at the top. Clay or loam has sometimes been used instead of gravel or sand. It makes an excellent surface at certain seasons, but in wet weather it becomes muddy and in dry weather dusty. It is especially objectionable when subjected to alternate freezing and thawing.

Reduction of Bulk.

Stones broken so as to pass through a ring 2½ inches in diameter occupy, when roughly spread, about 55 per cent of the thickness of the layer, leaving 45 per cent of vacant spaces between them. A layer therefore 6 inches thick would have 3.3 inches of stone and 2.7 inches of spaces. When completely solidified by persistent rolling with a heavy roller the 6-inch layer would be reduced to a thickness of less than 4 inches.

Convexity.

The convexity, that is, the rounding up or crowning, of the roadway may be stated either in its relation to the width of the roadway or as showing the slope from the centre to the edges: thus 1/18 means that a roadway 18 feet wide is 1 foot higher in the centre than at the edges, which is the same as saying that the slope from the centre to the edges is 4 inches to the yard. The following table may be convenient for reference:

1/18	=	4	inches	to	the	yard.
1/24	=	3	"	"	"	"
1/30	=	$2\frac{2}{5}$	"	"	"	"
1/36	=	2	"	"	"	"
1/42	=	$1\frac{5}{7}$	"	"	"	"
1/48	=	$1\frac{1}{2}$	"	"	"	"
1/54	=	$1\frac{1}{3}$	"	"	"	"
1/60	=	$1\frac{1}{5}$	"	"	"	"
1/66	=	$1\frac{1}{11}$	"	"	"	"
1/72	=	1	"	"	"	"
1/84	=	$\frac{6}{7}$	"	"	"	"
1/96	=	$\frac{3}{4}$	"	"	"	"

The convexity given to the old roadways was excessive, the cross-section showing a slope from the centre of $2\frac{1}{2}$, 3, and even 4 inches to the yard. The evident purpose was to promote good drainage and thereby insure the solidity of the roadway; but the fact is that water will drain readily from a surface that may have but very slight inclination, provided the surface is even. The important point is to keep the surface even, and to prevent the formation not only of ruts, but even of permanent tracks, since these hold the water and prevent its proper drainage, however great may be the convexity of the roadway. The more rounded the surface the greater is the tendency of travel to keep to the middle, and a track once begun is worn steadily deeper. If the roadway be even and moderately crowned, wagons pass equally well over every part of it, and no permanent tracks will be made. Hence the surface should be such that travel will use indifferently the whole width. The less the convexity the more advantageous for travel. *The great secret of the maintenance of a stone roadway in good order is to facilitate travel over its whole width.*

Provided the roadway is kept in proper order, a convexity corresponding to 1 inch to the yard is sufficient for good drainage, and favors free circulation over the whole width. This is the convexity prescribed by Macadam, and is the one adopted on the best English and French roads. This is of course after the roadway has become thoroughly solidified and reached its normal condition under travel. For a newly-built road, however, and for ordinary stone roads in general, a slope of 2 inches to the yard is found best in practice.

Résumé.

The successive steps in the actual building of a stone road are ordinarily as follows:

The grade is first determined, whether it be for a road on an entirely new line or for an old one which is to be made over. Next the width and convexity to be given to it are decided on. Then follows the preparation of the bed to receive the broken stone. The essential conditions are that the surface of it shall be well drained and that it shall be hard, dry, and smooth, so that the stones, when compacted under the roller, shall not penetrate it. A few turns of the roller over it are often advisable. Some engineers, especially in England, spread a layer of gravel 2 to 3 inches thick before rolling, unless the ground be hard and dry. As to whether the bed shall be made horizontal or have the convexity of the finished roadway, practice varies. If horizontal, the stone layer is made thicker in the middle, where the wear is inevitably greatest, in order to give the required convexity. Otherwise the stone layer is of uniform thickness throughout, and the convexity of the earth bed gives drainage to any water that may find its way there. But if the stone layer is as impermeable to water as it should be, there would be none to drain off. In view, however, of possible imperfection in the work, the bed had better be convex.

Upon this bed is built the stone roadway, whether the Telford system with foundation, or the Macadam system without foundation, be adopted. The latter, as has already been stated, is the one exclusively used in France to-day.

Under the Macadam system the stone layer consists of stone, generally of one kind only, broken as nearly as practicable to a uniform size. Sometimes this is all spread at once and then rolled. If, however, the road is to be of standard thickness, it will be more solid and durable if the total quantity be spread in two layers, and the first is well rolled before the top one is spread. This is especially true if a lighter horse-roller is used instead of the heavy steam-roller. If no roller at all is to be had, then ordinary travel must do the work of compacting the stone, which was Macadam's original method. Rollers were first used in England about 1830. He spread 4 inches at first, assuming that 10 inches in all of loose stone were to be used, and when this had become sufficiently solid under travel, a layer of 3 inches more, which is, in turn, subjected to travel, and finally the top layer of 3 inches. At the present day, however, the great convenience and advantage of thorough rolling is fully appreciated. It not only brings the road at once into perfect condition, but it consolidates far better the mass of stone and makes the roadway the compact, impermeable body desired.

The heaviest roller, within practicable limits, is the best, and the greater the compression the more solid is the roadway. The number of times a roller must pass over a given point in order to secure complete solidification varies much with different circumstances.

1. It increases in proportion to the hardness of the stone. Assuming that the layer is 3 inches thick, and that a 10- or 12-ton roller is used, 50 times are sufficient with ordinary limestone, 50 to 75 times with granite, and 90 to 100 times with porphyry or trap.

2. It increases with the thickness of the layer to be rolled, but not in proportion to the thickness.

3. It is more if the stones are dry than if they are wet. Abundant watering at the moment of rolling facilitates compression, transforms the loose stones into a monolith, avoids the pulverization of the stone, and is every way more economical. Great care must, however, be taken to use the water in such way and quantity as not to soften the ground beneath. Where this is not exceptionally hard and solid it would be better at first to roll dry.

When the rolling is nearly finished, and not till then, a layer 1/3 of an inch thick of clean gravel is spread over the surface, and the road is ready for travel.

IV. MAINTENANCE AND REPAIR.

The importance of keeping a stone road always in good condition is so great from every point of view that it would seem unnecessary even to mention it were it not that in so many cases roads thoroughly well made have been allowed to deteriorate simply for want of moderate care and attention. It seems hardly worth while to incur the necessary expense of building a good road if it is to be so neglected. The old adage, "A stitch in time saves nine," is emphatically true of stone roads.

In the maintenance of such roads there are two operations, viz., the use of the material to replace that used up and the removal of mud and dust caused by wear. If either of these is badly done, or not done at the proper time, the roadway deteriorates.

There are also two quite distinct methods of repair.

A. That which, for want of a better name, may be called *patchwork repair*. This is the older method, and, though still employed upon nearly one half of the *Routes Nationales*, is being replaced gradually by the other method.

B. That by *general recharging*. This, the more modern one, is favored where it can be applied, but it necessitates the use of a horse or steam roller.

A. Patchwork Repair.

This method consists essentially in restoring annually to the roadway a quantity of broken stone equal to that lost by wear during the year, and this not by spreading a layer uniformly over the surface, but by repairing isolated spots or *patches*, where from wear or other cause holes or depressions show themselves. The intention is not only to keep the surface even and insure perfect drainage, but also to preserve constantly the normal convexity and thickness of the stone layer.

When this method is faithfully carried out the result is an excellent road, well maintained, but at high cost. When, however, it is carelessly or inefficiently applied, as is not unfrequently the case on less important country roads, the result is far from satisfactory. The roadman there simply spreads the broken stone, assigned to his section, at such points as he thinks require it, and then leaves it to ordinary travel to do the rest. This can never give a good road.

The obvious disadvantages of this method may be diminished if the following precautions are carefully observed: Notice the holes and depressions immediately after a heavy rain; mark them by lines forming rectangles around them; pick the space within these rectangles to a nearly uniform depth; separate the stones from the fine material and pack them well inside the space picked, adding more if required; make them solid with the pounder, without the addition of any binding material; repeat the pounding if later any of the stones be displaced.

Evidently much labor must be expended to get good results, for if the *patches* cover, say, a square yard each, a roadman will hardly be able to use more than 1½ cubic yards of broken stone a day, and consequently the length of road assigned to him must be disproportionately small. This method is simple but not economical, and should be used only where a "general recharging" is impracticable or unadvisable.

As, however, its adoption may be unavoidable, some further details may be noted. The roadmen have a tendency to frequently renew certain muddy or wet places, such as the bottom of a valley or in a dense wood, and especially on the flanks of the roadway. Such points are often muddy, not because the stone layer is too thin, for it not unfrequently is thicker there than elsewhere, but because the drainage is imperfect. The remedy is not to add more stone, but to scrape away the mud. The flanks of the roadway especially should be so treated, for they are always less worn by travel than the middle of the road, and any mud that may be there is largely accumulation of scrapings from the middle. The flanks in any case must be kept clean, and this is generally enough. If the roadway is not more than 16 feet wide these repair patches are needed only on the middle 10 feet.

Since this method contemplates the restoring for the whole length of the road an amount of stone equivalent to the annual wear, it is evident that more must be added than just sufficient to fill holes and depressions.

The way sometimes adopted is to spread at once on the many *patches*, the whole length of the section, the year's supply of stone assigned to it, and then leave it to travel to do the work of compacting. Nothing could be much more objectionable. The wagons avoid the loose stones as far as possible, and the roadway suffers in consequence. The proper way, assuming that no roller is used and that ordinary travel must do the work, is to force travel to pass over the whole surface by obstructing it in one direction and facilitating it in another. To effect this the first *patches* may be made along the middle of the road at intervals of about 50 yards, without reference to any depressions there may be between. These *patches* have the shape of elongated rectangles, about 3×8 feet.

The whole section having been gone over in this way, the roadman commences again at the original starting-point and makes new *patches*, checker-board fashion, alternately on the right and left of the first patches and midway in the space between them, care being taken to place them within the middle three quarters of the width of the roadway.

On the third trip he makes new *patches* between the second set, and so on, always observing the checker-board arrangement.

Thus in five trips the whole central part of the roadway has been covered, while travel has been induced, without serious annoyance, to change direction five times and virtually to pass over nearly the whole surface. When this has been well done the roadway is perhaps good enough, but is never perfectly solid and even.

The pounder is an indispensable tool in making good repairs, but the use of it is fatiguing, and is often abandoned or neglected. A two-horse roller is often used.

The *cleanness* of the stone added has already been emphasized in the section on road construction. It is equally important in repairs; hence the mixing of sand or gravel with it should not be allowed, for the reasons already given. The objection applies with even greater force to the use of clay or loam.

Repair of Tracks and Ruts.

Tracks and ruts are seldom found except on a roadway that has been badly cleaned or badly repaired. The first step is to scrape off the accumulated mud, dry as well as soft. Sometimes this alone will restore the road to tolerable condition, and unless the wheel-tracks have worn into the stone, slight obstacles may be placed, sufficient to turn the travel, and thus gradually restore the even surface.

Inexperienced workmen may seek to remedy the evil by filling the ruts with broken stone; but this rarely answers the purpose, for a new track will speedily be formed by the side of the old one.

If, however, the track, after being scraped, appears too deeply worn to be obliterated by the means already suggested, nothing remains but to treat it as a depression and thoroughly pound the stone in it. This is obviously a costly operation, and should be resorted to only to save the road from complete destruction.

The stone used for patchwork repairs should be of the same kind and degree of hardness as that of the existing road. It should be neither harder nor softer, or the road will wear unevenly. If softer, it is more easily worn and tends to make holes. If harder, it tends to produce little humps and to deepen the low spots about them. Thus a hard trap should not be used for patchwork repairs of a limestone road.

B. General Recharging.

This method presupposes the use of a horse or steam roller, and consists in allowing the roadway to wear away gradually until it has reached the minimum thickness compatible with sufficient resistance. When this condition of wear has been reached, the whole surface of the roadway is to be covered with broken stone, sufficient to restore it to its normal thickness and convexity; and this layer should be as thoroughly rolled as in the making of a new road.

The interval between two successive rechargings must depend, other things being equal, upon the amount of travel. It may be three or four or possibly ten years. During this period the roadway, if *entirely* neglected, would be covered with depressions and holes, more or less serious. An even and consequently uniform surface may be secured by means of the ordinary patchwork repair, restricted solely to this purpose, and with no intention whatever of restoring the annual wear. On roads where travel is moderate such repairs are scarcely needed at all for the first few years immediately following a recharging.

The advantages of this method are that it gives to the public a good road at all times, and is economical of material.

The disadvantages are, that a somewhat harder stone is required, and that the normal convexity is not maintained during the whole interval.

Stone roads, in fact, do not wear off uniformly over the whole width. The middle portion is inevitably most rapidly worn, and if the recharging is too long delayed the surface becomes hollowed, and is consequently not properly drained.

In France the tendency is to substitute this method for the older one, and in 1893 more than half of the stone for repairs was used in general rechargings. This method is used exclusively in general repairs of the macadamized streets of Paris.

Thickness of Rechargings.

The thickness of stone to be added must depend on the conditions in each case. Assuming that the roadway, when new, had a thickness of 8 inches, and that experience had shown this to be sufficient, so much stone only need be added as will restore the layer to its original thickness and convexity. As a road wears it gradually loses its convexity, becomes flat, and finally hollow along the middle if repairs are delayed too long. The sides are comparatively little worn and evidently require little or no fresh material. In general, then, the recharging may be confined to the middle portion 1½ to 2 feet from each edge of the roadway. In the majority of cases, provided the wear has not been allowed to go on up to the last possible limit, a recharging which when compacted has a thickness of 4 inches is amply sufficient. If the wear is well within this extreme limit an average thickness of 2¾ to 3 inches of new stone may suffice, say 1/3 of a cubic yard per running yard if the recharging is 12 feet wide, or if it is only 9 feet wide, 24 cubic yards per 100 yards. It is sometimes astonishing to see how, with even so slight a covering, an inferior road may be brought into excellent condition, provided it is well rolled.

A recharging only 8 feet wide along the middle is much better than nothing.

Picking of the Surface for Recharging.

When the surface of the roadway does not need recharging for its whole width, the part to be covered must be limited and defined by two furrows cut lengthwise of the road, in order to prevent the stone, which may be added, from spreading under the roller, and also to insure the better union of the edges of the new layer with the undisturbed margin of the roadway. These furrows should be carefully picked out. No other picking is necessary. The practice of picking up the whole surface of the width to be recharged is common enough, but the utility of it is questionable. Why destroy at considerable expense a portion of the solid layer, which is already as thoroughly compacted as it can be? Presumably the purpose is to insure a perfect union of the new stone with the old body of the road, but this can be effected quite as well in another way and with far less expenditure of labor.

A vigorous scraping and sweeping will thoroughly uncover the old surface. There is always a greater or less thickness of mud or dust on a roadway. If this is not removed it forms, after recharging, a thin layer of material, as objectionable as clay, between the old bed and the new—a layer analogous to that which separates two successive beds of any sedimentary formation. This layer should in any case be removed, and can be by thorough scraping and scratching with a stiff broom. If this is properly done there is nothing to prevent the perfect union of the new stone with the old solid road-bed. It is worse than useless to set an army of men with picks to break up this solid bed and do what had better be left undone. A good stream of water from a hose while the sweeping is going on aids greatly in the perfect removal of the fine material.

Rolling.

This is an operation as essential in the recharging as in the building of a road. It is just as important here as there to compact the broken stone into a solid mass and get rid of all cavities. By rolling, first, the broken stones are crowded face to face, and lie as closely together as their shapes will allow; second, the edges and angles are to some extent crushed, and the fine particles fill up the cavities. Of these two results the first is evidently the better, and should be facilitated as much as possible by diminishing the friction between the stones. The ideal roadway will be realized when they are so compacted that *no* cavities are left between them. This ideal may be approximately reached, when the stones are cubical and of uniform size, by abundant watering before and during the rolling.

Watering.

This watering is indispensable when a recharging is made at a dry time on a hard foundation. In such case the stones may well be deluged with water; the compacting of them goes on more rapidly and perfectly, and their union with the old roadway is more complete. The excess of water soon drains off, and the road, after a few days of fine weather, becomes exceptionally hard and solid.

At a dry time 350 gallons of water should be used daily for every 100 running feet. During a wet time less watering is necessary, and the operation is consequently more economical.

Binding Material.

No binding material should be mixed with the stones in a recharging any more than in the building of a road. Here as well as there a perfect bind, better and more enduring, may be secured by rolling than by the use of gravel. Gravel may, however, be advantageously used after the rolling has consolidated the stones, spread as a layer not exceeding one third of an inch thick, in order to fill the small interstices that may be left in the mosaic.

Some have strongly advocated a method, which consists in spreading on the old roadway a thin layer of sand or sifted gravel before the recharging. Upon this the broken stone is spread, thoroughly watered, and rolled. They claim that the sand or gravel becomes semi-fluid and is squeezed up among the stones, and that it acts in the same way as a binding material mixed with the stones. It certainly does favor the more rapid packing of the stones in a certain way, and is a less expensive operation than that recommended above, but it cannot fail to impair the final solidity of the road, and hence is not real economy. A recharging made with as much water as practicable and the least possible quantity of binding material will always be the solidest.

The rolling of a *new roadway*, as has already been stated, should be done in fine weather, when the surface of the foundation soil is dry and hard.

The rolling of *rechargings*, on the contrary, may better be done after several rainy days have helped to clean off the old roadway and to soften somewhat the surface.

The edges should first be rolled, and the centre not before both edges have been somewhat compacted. The first turn of the roller on the border should overlap about 8 inches on the old solid part. It will be remembered that the furrow, cut with a pick, was intended to narrow the part to be recharged, and was to be cut in such way as to form a shoulder against the thrust of the stone under the roller.

When one margin has been rolled the same operation is repeated on the other margin, and so on progressively toward the centre, care being taken that each turn shall overlap about 8 inches of the part already rolled; the stone should be thoroughly watered during the rolling. The rolling should be continued till the mass is solid and does not undulate under the roller or yield on the passage of a loaded wagon. *Not till then should the thin layer of binding gravel be spread,* not to penetrate into the body of the roadway, but only to fill the interstices of the surface.

A small quantity of the stone should be reserved to fill any depressions developed during the rolling and to keep the surface even.

If the surface of the old road be in very bad condition, with many holes and ruts, these last may be filled and pounded or rolled in order to prepare a tolerably even surface for the recharging proper. In the worst cases the recharging may be made in two operations, the lower layer being of inferior and less expensive stone. But in all cases the top layer should be of the *harder* stone (if there is any difference), never of the more tender, and under no circumstances an indiscriminate mixture of hard and soft stone.

To insure perfect work the road should be watched for some little time after a recharging and watered regularly. Stones that may have become loose should be removed; any parts injured by some accidental cause be pounded; and by occasional sweeping all wheel-tracks obliterated, in order that travel may be induced to circulate over the whole width.

The following is given by Monsieur Debaure as an average cost, per cubic yard of material, of a recharging covering a width of about 10 feet, with an average thickness of 2½ to 3 inches. This allows 8 to 9½ cubic yards per 100 running feet. It is exclusive of the cost of the broken stone and gravel. It assumes the use of a hard stone, like trap for instance, rolled dry with a 10-ton steam-roller. The cost would be about 20 per cent less if rolled wet and if a softer stone were used. The average wages of an ordinary roadman are from 65 to 70 cents a day.

	Cost per cubic yard. Cents.
Picking the furrows and preparation......	1
Spreading the broken stone..............	7
Finishing off and spreading gravel........	4
Cost of water and watering................	13
Rolling, oiling, and small repairs of roller.	13
Wear of roller and large repairs....... ...	5
	43

A 10-ton steam-roller can effectively roll in a day 328 running feet (100 metres) of such a recharging as above indicated. The cost, if a horse-roller were used, would be about 30 per cent greater.

In the Department of Oise, under M. Debaure's charge, 130,000 cubic yards of broken stone are used annually for general rechargings.

Modified Recharging.

After a very severe winter or following an exceptionally heavy travel a roadway may have become very uneven, full of holes and ruts, and quite out of order, while the stone itself is not much worn. The time for a regular recharging has not yet come, and yet heavy repairs are demanded immediately. Recourse in such case may advantageously be had to a modified recharging, with use of the roller. From 4 to 8 cubic yards of stone per 300 feet of length, corresponding to about 1/6 to 1/3 of a regular recharging, may be spread at once where needed along the middle of the road and in the low spots, the edges of these spots having first been picked. Wet weather is availed of for this operation, and the roller is passed about a dozen times at most over the stone.

This operation, if well done and at a favorable season, gives excellent results, and restores to good condition a roadway that in appearance is nearly ruined. This, however, should be regarded only as a remedy in an emergency, and is not to be substituted for the system of general recharging. But it is infinitely better than the method of patchwork repair, as generally applied. These *patches*, when made all at one time, in a large number of spots, cause great annoyance to travel, and almost never effect an improvement commensurate with the expenditure.

Scraping and Sweeping.

The removal of mud and dust as soon as it is formed is necessary to keep the roadway in perfect order, and the roadway suffers just in proportion as this is neglected. In no other way can the formation of tracks be so well prevented, and the complete drainage of the surface insured.

Typical French Roads.

The following sections of typical French roads, taken from Debaure's treatise, shows the methods of construction adapted to different conditions of topography and travel:

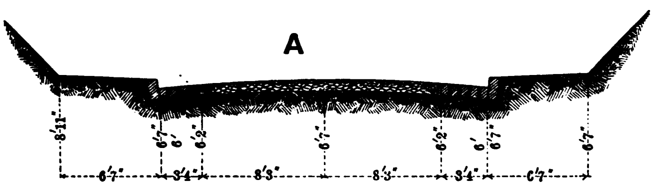

FIG. 4.

Fig. 4 is a section of the type of road in the Department of Seine-et-Oise, and is regarded as a good one where there is considerable travel. The macadamized portion is 16½ feet wide, with paved edges each about 3 feet wide; the sidewalks are about 6 feet wide, with a slope of 1 in 20. The convexity of the macadam is 1/40, or nearly 2 inches to the yard from centre to edge.

Fig. 5 is the type of roads in the Department of Bas-Rhin. The width of macadam is 19½ feet, with a gravel or grass margin on each side6 ½ feet wide. The ditches are 5 feet wide at the top and 20 inches deep. The macadam is unnecessarily wide, 16½ feet

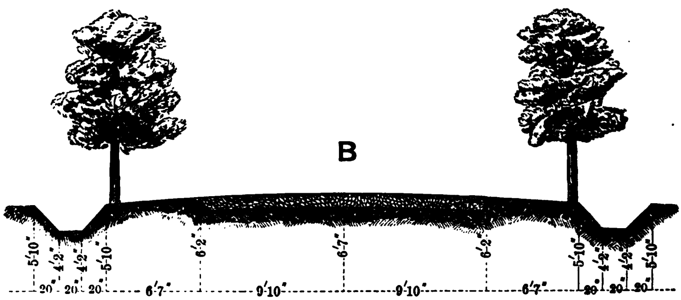

FIG. 5.

being amply sufficient. The convexity is 1/50, or 1½ inches to the yard.

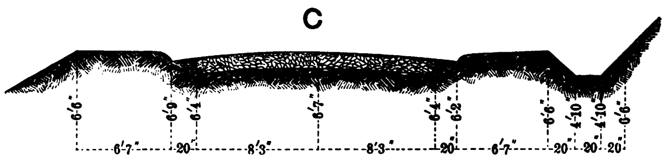

FIG. 6.

Fig. 6 represents a type in the Department of Loiret. The macadam is 16½ feet wide, with gravel edges each 20 inches wide, and raised margins of turf 6 feet wide. The drainage into the side ditches is effected by means of small cuts at short intervals through this turf margin. The convexity is 1/50, or 1½ inches to the yard.

Fig. 7 is a section of one of the "Routes Nationales" in the Department of Haute-Vienne, where the road is built upon an embankment. The macadam is 19½ feet wide; upon one side a footway 3 feet wide is

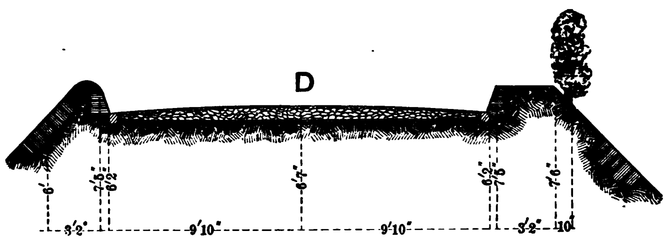

FIG. 7.

raised 18 inches above the edge of the macadam. The drainage is by pipes or uncemented but covered stone drains passing under this sidewalk. The convexity of the roadway is 1/40, or nearly 2 inches to the yard.

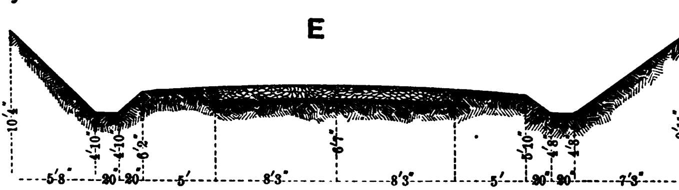

FIG. 8.

Fig. 8 represents a departmental road in the Department of Eure. The width of the stone portion is 16½ feet, with gravel or turf margins each 5 feet wide. The total width, including ditches, is 33 feet.

The stone roadway is formed of two layers, each 6 inches thick; the bottom layer is of large stones, and the top layer of broken stone $2\frac{1}{8}$ inches in diameter. The convexity is about 1/36, or 2 inches to the yard.

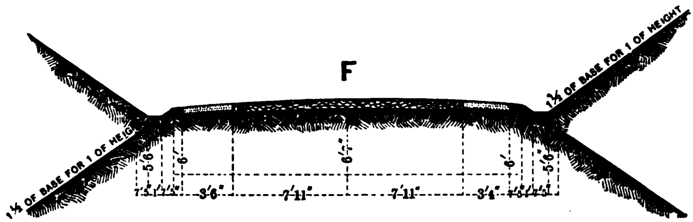

FIG. 9.

Fig. 9 represents a road of the first class in the Canton Vaud, in Switzerland. The width of the macadam is $15\frac{3}{4}$ feet, which will allow two carriages to pass, with margins each 3 feet wide of gravel. The convexity is 1/40, or nearly 2 inches to the yard. The slopes of cuts and embankments are generally 1 of height to $1\frac{1}{2}$ of base. Slopes steeper than that would be gullied, and difficult to maintain.

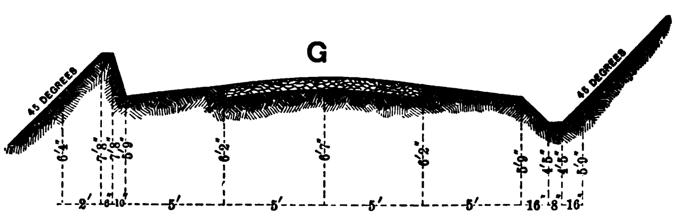

FIG. 10.

Fig. 10 is the section of a country road in the Department of Indre-et-Loire. The macadam is 10 feet wide, flanked with a margin on each side of 5 feet of gravel or turf. For roads of this kind 10 feet of macadam is quite sufficient. A width of 13 feet, which width is often adopted, has the disadvantage of being unnecessarily great for one carriage, and yet not enough for two. The convexity is 1/20, or 3½ inches to the yard, which is excessive.

TREE PLANTATIONS.

IN a country so thickly populated as France the economical use of all available land is a matter of importance, and the desire to utilize the margins of highways, which would otherwise be waste land, by the growth of trees has been one reason why the planting of trees upon the borders of most of the public country roads has received so much attention and care. But the reasons, equally strong there and of greater weight in our country, are the agreeable shade which trees give to the traveller during summer, and the influence they have in preserving the roadway during periods of dryness. In hilly and mountainous districts, where the deep winter snows cover everything, the trees are especially useful in marking the line of roadway.

It is therefore not surprising that tree-planting on the highways has for a century been the subject of royal decrees and legislative enactments, determining the kinds of trees to be planted, manner of planting, care of them, penalties for injury to them, etc. For instance, in 1851 it was ordered that the trees planted should be of species appropriate to the soil and climate, and as far as practicable those that would have a marketable value, such as elm, ash, oak, and chestnut among the harder woods of slow growth, and among the softer woods poplar, plane, sycamore, and acacia. Certain kinds, such as fruit-trees, walnut, wild cherry, and apple, were to be always excluded.

In 1880 the report of the engineers was adverse upon certain plantations of cherry, walnut, pear, apple, almond, chestnut, and mulberry trees, upon the ground that the fruits were stolen and the trees injured. Forest trees were preferred.

The utility of shade-trees in preserving the surface of the roadway during the dry heat of summer is the more evident where the material of which the road is built is quickly drained. One result of the constant care bestowed upon the main highways at the present day is that they are solid and perfectly drained, and in the majority of cases suffer more injury from dryness than from moisture. Hence shade-trees are of special value on long stretches of level road in an open country swept by drying winds. On the other hand shade-trees should not be planted in low, wet places, or where the roadway is not readily dried.

The method of planting is influenced by the width of the road. Many of the old *Routes Nationales* were laid out originally over 65 feet wide, where to-day a roadway of 16 feet width is amply sufficient for present travel. The turf margins are in such cases frequently planted with a double row of trees upon each side of the roadway. As a general rule, when the roads are 50 feet or more in width, two rows, 10 feet

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COST OF CONSTRUCTION.

Statements of the cost of building roads, unaccompanied by full details of the conditions in each case, have only a general interest. Not only are the elements which make up the cost different in different countries, but they are by no means the same in all parts of the same country, or even of the same district.

The amount and kind of travel to be provided for, the importance of the road and its width, the grading required, the special engineering obstacles to be overcome, the cost of broken stone, the local wages of labor and other similar considerations necessarily modify very materially the cost in each case. It is one thing in New England, where gravel is abundant and good rock near at hand, and quite another on the broad prairies of the West.

This, then, being understood, the following statements of cost are given for what they may be worth as general indications:

UNITED STATES.

Mr. James Owen* states, as the result of many years' personal experience in building roads on the Telford system in New Jersey, that "roads built in the manner I have described [6 to 8 inches thick including the stone foundation] cost in Essex County, N. J., 60 to 80 cents a lineal foot, 16 feet wide, according to their thickness and distance the material has to be hauled, including foundations of quarry-stones. This would be $3000 to $4000 a mile. By using local stone for foundation and local help in hauling, and as much as possible local labor, and also reducing on many of the local roads to 14 feet and even 12 feet, I think the cost throughout the State [Massachusetts] might be placed at $2500 per mile, provided due economy and wise administration are secured."

FRANCE.

The following figures are compiled from the returns published by the Minister of the Interior:

Chemins Vicinaux.†

During the period of six years, from 1881 to 1886, inclusive, there were built, under the operation of the

* Address on Highway Construction in New Jersey. By James Owen, C.E. Pub. of the Mass. Soc. for Promoting Agriculture, 1893.

† See Appendix, "Classification of Roads in France."

law of March 12, 1880, 25,994 miles of stone road at a total cost of $57,404,789. They are subdivided into three classes:

Class of Road.	No. of Miles.	Average Cost per Mile.	Total Cost.
Chemins de grande communication..	3,486	$2,926.50	$10,201,820
Chemins d'intérêt commun..........	5,081	2,309.16	11,732,832
Chemins vicinaux ordinaires........	17,416	2,036.64	35,470,137
	25,983	$2,209.32	$57,404,789

These general figures cover the whole cost of the roads, excepting for bridges, culverts, and such structures. They include not only the cost of the roadway proper, but also the expenditure, whatever it may have been in each case, for grading and the right of way, where necessary. Unfortunately the reports do not show separately these special expenditures, or the cost of different parts of the work, labor, material, etc., and hence do not admit of as complete an analysis as would be desirable. Such as is possible is given below.

The returns are from 86 of the 87 *Departments* into which France is divided, and give the number of miles of each class of road built and the total cost in each one of the *Departments*. The range of cost is very great. Thus in 6 *Departments* all of the roads, aggregating 400 miles, were built at a cost of not exceeding $800 a mile. In 13 *Departments* 310 miles cost approximately $5600 a mile, and in 3 *Departments* 380 miles cost about $7200 a mile.

Obviously the conditions of every sort must have been exceptionally faverable in the first case, and very exceptionally unfavorable in the last two cases. Between these extremes are all grades of cost, but the returns show that—

Chemins de grande Communication.

Number of miles built in 86 *Departments* is $3486\frac{3}{4}$.

No. of Depts.	Percentage of $3486\frac{3}{4}$ Miles.	Approximate Cost per Mile.
17	43	$1600
7	7	2400
18	20	3200
8	7	4000
4	6	4800
7	5	5600

Chemins d'Intérêt Commun.

Number of miles in 86 *Departments* is 5081.	Percentage of 5081 miles.	
22	45	1600
13	22	2400
17	21	3200
2	1	4000
4	2	4800
6	2	5600

Chemins Vicinaux Ordinaires.

Number of miles in 86 *Departments* is 17,416.	Percentage of 17,416 miles.	
7	11	1300
17	37	1600
15	18	2000
16	17	2250
11	11	2550
5	3	2900
5	3	3200

From which it appears that nearly one half of the whole number of miles of each class cost approximately $1600 a mile, that being the average cost per mile in each one of 56 *Departments*.

COST OF MAINTENANCE.

Routes Nationales.

These are maintained by the national government. The annual appropriation covers expenditure of every kind for ordinary and extraordinary repairs and improvements, and is apportioned among the 87 departments, generally in proportion to the number of miles taken in connection with the amount of travel.

Great care is taken to ascertain what this travel is, in order to insure an equitable distribution of the appropriation. * Once in six or seven years a commission of competent officials of the Bureau of Bridges and Roads thoroughly investigates the question. Their labors extend through twelve months, and their report is full of elaborate and carefully analyzed details. The choice of the several posts of observation is evidently one of the most difficult and important parts of the work. The 23,500 miles (including 1500 miles of block-stone pavement) are divided, according to circumstances, into sections of two to ten miles each, but averaging four and one half miles. The posts of ob-

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* Ministère des Travaux Publics. Routes Nationales. Recensement de la Circulation en 1888.

servation were (in 1888) 4734. The point was to determine the amount of travel that passes over each section during each twenty-four hours of the year. It was assumed that an exact record of what passed each post during 28 days, selected out of the twelve months, would give a fair average. Accordingly the record was made every thirteen days from January 3d to December 19th, thus giving seven days and each day of the week in each quarter of the year.

The "unit" adopted to express the amount of travel was each horse harnessed to a loaded wagon, and in order to reduce all the observations to this standard unit the following values were given, viz.:

1. Each horse hauling a public vehicle or a cart loaded with produce or merchandise...... 1
2. Each horse hauling an empty cart or a private carriage.............................. 1/2
3. Each horse, cow, or ox unharnessed, and each saddle-horse............................ 1/5
4. Each small animal (sheep or goat)......... 1/30

The results of these extended observations were accepted as giving a very close approximation to the actual amount of travel, as affecting the wear of the roadway.

The official report gives the average travel in each *Department*. Excluding a few *Departments* where the travel was quite exceptionally large or small, it ranged generally between 100 and 400 "units" in the twenty-four hours. The general average of all *Departments* was 170.6 "units."

It is generally assumed that, where the conditions are the same, the wear of the roadway is in direct ratio with the amount of travel, but the conditions may vary considerably. A mountain road subjected to the wash from heavy rains and melting snows may easily lose more material from its surface and deteriorate more rapidly with little travel than a much-frequented road in a level country.

The quality of the broken stone used in different districts influences very materially the quantity required for repairs. As has already been stated, in a scale of quality from 0 to 20, the general average of all *Departments* is 10.85. In two of the *Departments* the average quality is only 6.40 and 6.90, and in four it is, respectively, 16.23, 16.33, 16.65, and 16.95. Considerable quantities of qualities 3 and 4 are used. It is evidently thought good economy to use to so large an extent the inferior but cheaper material near at hand, rather than the better but more costly one brought from a distance.

TOTAL AVERAGE COST, LABOR AND MATERIALS.

From the *Official Reports* it appears that there are in France 321,803 miles of stone roads of the various classes, upon which the annual expenditure for maintenance, including improvements and repairs, is approximately $31,551,860.

	Miles.	Annual Total Cost.	Annual Cost per Mile.	
Routes Nationales.......	22.009	$4,333,500	$225	During year 1893
Routes Departmentales..	16,188	2,794,723	172	Annual average
Grands Vicinaux	128,522	15,835,100	123	for three years,
Petits Vicinaux...	155,093	8,488,537	55	1886, 1887, 1888.
	321,803	31,551,860		

These figures represent the outlay for materials and for labor on the roadway proper. About 45 per cent must be added thereto to cover expenditure for water-courses, sidewalks, planting of trees, and for general administration.

ROUTES NATIONALES.

General Averages for Year 1893.

Number of miles..................................	22,009
Average travel in 24 hours, "units"........	170.6
Broken stone, including 7½ per cent of binding gravel, per mile and 100 "units," cubic yards..................................	49.
Quality of stone, scale 0 to 20, average... ...	10.85
Average cost of stone, per cubic yard.... ...	$1.17
" " of binding gravel, per cubic yard.	0.36
Labor cost per mile and 100 "units"........	30.71
" " " cubic yard of material used....	0.63
Average wages of roadmen per day..........	0.55

Total average cost per mile and 100 "units:"

Materials.................... $58.75

Labor....... .... 30.71–$89.46

The Average Cost of Stone.

The average cost in the several *Departments* that make up this general average varies very considerably, and seems to depend as much on the proximity of the quarries and cheapness of quarrying as on quality of stone. The average in 12 *Départments* was, severally:

$0.53	per	cubic	yard	of	quality....	No.	8.04
0.56	"	"	"	"	" ...	"	7.19
0.60	"	"	"	"	"	"	10.47
0.61	"	"	"	"	" ...	"	9.70
0.67	"	"	"	"	"	"	9.25
0.73	"	"	"	"	"	"	6.40
1.96	"	"	"	"	"	"	15.45
2.20	"	"	"	"	" ...	"	13.80
2.27	"	"	"	"	"	"	16.33
2.38	"	"	"	"	"	"	16.95
2.40	"	"	"	"	"	"	10.91
2.78	"	"	"	"	" ...	"	14.25

Average Cubic Yards per Mile and 100 "Units."

The average consumption in some departments is as low as 26 to 30 cubic yards, and in others as high as 60 to 65 cubic yards. This wide divergence in quantity used is due in part to differences in the quality of the stone used, the inferior stone wearing out faster; but aside from that there are differences the reasons for which are not stated in the reports.

The writer was unable to obtain corresponding details and analysis of expenditures for the maintenance and repair of the *Routes Departmentales*, *Grands Chemins Vicinaux*, and *Petits Chemins Vicinaux*.

PAVEMENTS OF PARIS.*

The excellence in general of the street pavements of Paris and the intelligent care bestowed upon them by the government and the highly educated body of engineers more immediately in charge justify a careful study and a somewhat detailed account of the mode of construction and maintenance of the several kinds, the conditions to which each is suited, as well as the reasons for the adoption of one or another, and in general the conclusions reached after many years of experience and experiment.

The simple facts that the area of the street pavements exceeds 10,500,000 square yards, in addition to 8,288,000 square yards of sidewalks, alleyways, etc., all under the same direction, and that the expenditure for the year 1893, exclusive of the salaries of officials and the cost of new constructions, amounted to $4,910,000, are sufficient to indicate the great importance of the subject.

Organization.

The "Service of the Public Ways" is primarily under the Préfet of the Seine, who represents the

* The greater part of what relates to the Pavements of Paris is derived from "Notes à l'appui du Compte des Dépenses de l'Exercice 1893," by Monsieur L. Boreux, l'Ingénieur en chef de la Voie publique, and from other official documents furnished by him to the writer.

national government, but is specially under the direction of the Board of Public Works of Paris, and immediately in charge of an engineer-in-chief of the Ponts et Chaussées. Under him are eight engineers of the Ponts et Chaussées, each of whom has the responsible charge of one of the eight sections into which the twenty wards (*arrondissements*) of Paris are divided. The engineer-in-chief has under his immediate command 15 superintendents, 22 overseers, 17 assistants, and 2 office-boys. Under the eight section engineers there are in addition 108 superintendents, 111 overseers, and 99 assistants.

Each section is subdivided into six districts, each under the immediate charge of a superintendent and one or more overseers or assistants, according to the importance of the service.

In all of the sections excepting one the street-cleaning is under the direction of the district superintendents.

The figures are unfortunately not at hand to show accurately the total number of workmen of all classes employed in the street service, but in 1893 the number was considerably more than 5000, of whom 3500 were engaged in street-cleaning.

The engineer-in-chief has executive control, since August 1, 1892, of—

1. All new constructions, and the maintenance of existing highways (streets, sidewalks, alleyways, etc.); and

2. The cleaning and watering of these public ways.

Under the first head are embraced—

(*a*) Block-stone pavements and the working of the quarries belonging to the city;

(*b*) Macadam pavements and the steam-rollers, including the shops for the repair of the rollers;

(*c*) Asphalt pavements;

(*d*) Wooden pavements, including the purchase and preparation of the wood;

(*e*) Bridges, foot-bridges, and the various constructions connected with the care of the public ways;

(*f*) Control of the cements, the laboratory for testing materials, and the collecting of statistics relating to the public ways;

(*g*) Sidewalks, alleyways, improved surfaces, etc., and the supervision of the establishments for the preparation of powdered asphalt and of bituminous mastic;

(*h*) The laying out of roads for private owners.

The cleaning of the streets includes the watering, sweeping and removal of mud, removal of snow and ice in winter, removal of house refuse, and the management of the shops for the repair of material. These shops serve also for the repair of the steam-rollers and tools used in paving, but 60 per cent of the expense is chargeable to street-cleaning.

Different Classes of Streets.

From the point of view of maintenance and control the streets are divided into "Classified" and "Unclassified." The former are public highways in every sense, and are public property. The adjacent proprietors arc charged in the first instance with the whole cost of the first pavement. After the street has been accepted as a public way it is maintained at the public cost.

The "unclassified" streets are private ways, and are wholly maintained at the cost of the adjacent owners.

Foundation.

All of the wood, asphalt, and a portion of the block-stone pavements of Paris are laid upon a specially prepared cement-concrete foundation, which, under the same conditions, is the same for all.

By the requirements of the contracts the concrete must be composed of two parts by measure of pebbles and one part of sand, with which the cement, generally Portland, must be mixed in the following proportions, by accurate measurement and weight:

Pebbles, by measure..............	1 cubic yard
Sand, " "	½ " "
Portland cement, by weight	420 pounds

None of the pebbles must be more than 2½ inches nor less than 3/4-inch in diameter; they must be made perfectly clean by abundant washing. The sand must be free from all earthy matter and be screened so as to contain no grains less than 1/12 nor more than 1/6 inch in diameter. The Portland cement is thoroughly tested before being accepted.

The concrete must be made on movable beds as near as possible to the point where it is to be used, the pebbles, sand, and cement being mixed dry with shovels in such way as to insure an intimate mixture. Water is added, and the concrete shovelled at once on to the ground prepared to receive it. It is then brought up to grade and the surface made even.

After not less than three days a coating of cement and sand about an inch thick is spread, and the surface made perfectly smooth and even. This mixture is in the proportion of 760 pounds of Portland cement to a cubic yard of sand.

This concrete foundation has uniformly a thickness of 6 inches, including the cement coating. In exceptional cases, where the bad condition of the earth below demands it, the foundation is made 7 or 8 inches thick.

Maintenance of Street Pavements.

It is assumed that the wear of a pavement depends, first, on the number of vehicles using it; second, on their weight; third, on their rate of speed. These three causes act simultaneously in wearing the pavements of Paris to a degree not exceeded in any city of the world. The effect of the numerous three-horse omnibuses is specially noticeable. Their weight, which amounts to 12,000 pounds when fully loaded, their speed varying from 5½ to 6¼ miles per hour, and their frequent stops, all combine to make them a very destructive agent. The speed of the public cabs has also sensibly increased within the past fifteen years.

Different Kinds of Pavement.

	Area Jan. 1, 1894.	Per cent.
1. Block-stone.......	7,541,258 sq. yds.	71.5
2. Macadam.........	1,724,632 " "	16.3
3. Asphalt...........	402,394 " "	3.8
4. Wood.............	886,236 " "	8.4
	10,554,520 " "	100.0

All of the pavements of Paris fifty years ago were either cobble-stone, block-stone or macadam, the former in those sections where travel was heaviest, and the latter where travel was relatively lighter. As travel increased in the streets with macadam pavement the wear and consequent cost of maintenance increased proportionally, until in any given street it became evidently more economical to substitute the more costly but durable block-stone, with its moderate annual cost of maintenance, in place of the macadam, with its rapidly increasing annual outlay for repairs. To-day 71 per cent of the street pavement of Paris is of block-stone, and 16 per cent is of macadam.

The desire, however, in certain sections and streets for a pavement which would obviate the noise of the one and the mud and dust of the other has led to the introduction first of asphalt and later of wood. The experiments with asphalt date from 1837, but it was not until 1855 that the mode of construction in use to-day was first applied.

The first wood pavements were laid in 1881.

On the 1st January, 1894, the asphalt pavements represented 3.8 per cent and the wood pavements 8.4 per cent of the whole pavement of Paris.

The tendency to-day is to substitute asphalt and wood, mainly the latter, for block stone and macadam, especially for macadam. In certain outlying parts of the city macadam will still be retained, and in others, from the nature of the traffic, block stone will still be preferred, but the use of wood is decidedly on the increase.

On the 1st January, 1894, the total area of pavements of all kinds was 21,516 square yards greater than on January 1, 1893; but the area of the block-stone pavement had during the year decreased 31,215 square yards and that of macadam 25,000 square yards, while that of wood had increased 77,381 square yards, and during the year 1894 it had further increased more than 124,000 square yards.

The area of asphalt had increased during the year 1893 only 2800 square yards.

Wood pavement is obviously the favorite one. Its advantages as compared with block stone and macadam have already been stated; it is smooth, noiseless, agreeable to drive over, easily kept clean, and is rapidly relaid when worn out.

Asphalt has all of these advantages, but has the disadvantage of being rather more slippery when wet.

Its use is in general restricted to narrow streets, less open to the sun and winds.

Wood is in general laid on the broader streets, to which the sun and winds have free access.

Neither asphalt nor wood is considered a suitable pavement for streets where the grade exceeds 4 feet in 100. This condition is the more necessary in Paris, where all horses at all seasons are shod smooth —a local custom, the reason for which is not apparent, as there seems to be no law requiring it. It undoubtedly diminishes the wear on both asphalt and wood, but necessitates the sprinkling of sand or gravel wherever the surface becomes slippery from any cause.

I. BLOCK-STONE PAVEMENT.

The area is 7,541,258 square yards. It is maintained partly by contract, and partly by the city directly with the force of the street department. The number permanently employed in this work is about 444, divided into 75 gangs ("brigades"), comprising together 43 inspectors, 84 foremen, and 317 ordinary paviors. The wages per month of 26 days of 10 hours each are as follows—

Inspectors of the first class	$33
" " " second "	31
Foreman	30
Pavior of the first class	29
" " " second "	28
Helpers (five classes)	$25 to 28

Construction and Maintenance.

All wholly new pavement is laid by contract.

The maintenance includes—

1. Reconstruction with the substitution of new stone for old;

2. Large repairs, which consist in taking up the old pavement and in repaving with selected blocks that are more or less worn;

3. Small repairs in such spots as require them.

The reconstructions and large repairs are all made by contract. In the case of reconstruction the old

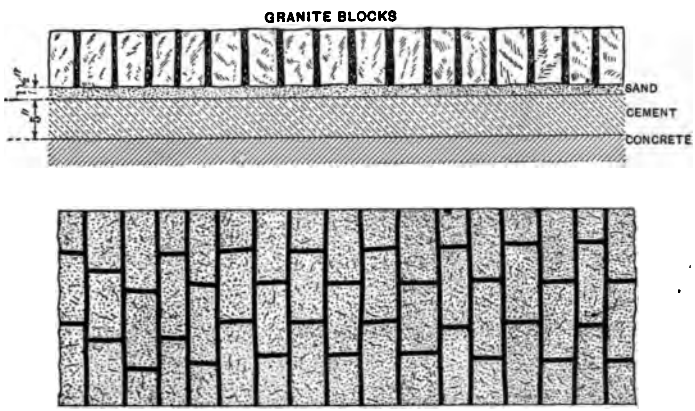

FIG. 11.

blocks are carefully sorted, the best are reserved for large repairs elsewhere, and the others are piled in the yards to be recut, or to be discarded entirely if no longer utilizable.

It is considered necessary that not less than 1/35 of the entire area of block-stone pavement should be reconstructed every year with new stone.

All of the older pavements were laid upon the earth, bedded in a thin layer of sand. Within a few years, however, a certain area has been laid upon the concrete foundation already described, in a layer of sand not exceeding 3 inches thick.

The results have been so satisfactory that the general adoption of this cement-concrete has been limited only by its cost. In 1894 rather more than 1/22 of the entire block-stone pavement was on concrete foundation.

Kinds of Rock and Dimensions.

The standard dimensions now approved are a length 1½ times the width and a uniform depth of 6¼ inches; thus the sizes 6¼″ × 4″, 7″ × 4¾″, 8″ × 5½″, all 6¼ inches deep, are accepted.

There are five kinds of rock used—the porphyritic granite of the Vosges Mountains, the porphyry from Belgium, and three varieties of a granular quartzose rock (*grès quartzites*), more or less compact.

The Belgian porphyry is but little used at present, hard and durable as it is, because it tends to become polished and slippery under wear. This is a point of more importance perhaps in Paris than elsewhere, since all horses there are shod perfectly smooth at all seasons.

The Vosges granite and the hardest of the quartzitzes have given the most satisfactory results, but the softer quartzites have been most used in the past as being the least costly. The city owns and works some quarries, but relies on them mainly as a means of determining the proper cost of the stone and of defeating any combination of the contractors.

Nearly all of the stone used is furnished by contractors, who are required to deliver it in one or other of the eleven depots or yards where it is to be stored. A sufficient force is employed to receive it, and at the same time to rigorously inspect each block and to reject all that are deficient in quality of stone, exactness of dimensions, or perfection of cutting.

Contract for Laying Block-stone Pavement.

All of the contracts covering the block-stone pavements of Paris extend over the same period. The last were for 2½ years and expired July 1, 1895. The form of the contract was the same in all, but in general the paving of each of the twenty wards (*arrondissements*) was the subject of a separate bid and contract, and no more than two contracts were awarded to any one bidder.

The probable expenditure under each of these eighteen contracts is stated before the bidding, but this is not made binding upon the city as a condition of the contract.

The contract is very full and specifies in great detail the materials to be used, the kind of work that may be required, the manner in which it shall be done, etc. Attached to it is an elaborate schedule of prices of the different kinds of labor, of the several materials used (except paving-blocks), of recutting old blocks, of all excavations, etc. The several bids are made at a greater or less discount from this schedule of prices, which discount applies to every item of the schedule. In the last contracts this discount ranged from 24 to 38 per cent, averaging about 33 per cent.

The contractor must do the work, whatever may be required, at the time ordered.

The rate of work (new or reconstructions) must be 50 linear feet a day, whatever the width of the street. In addition five days are allowed for preparatory work if the pavement is to be laid in sand simply, and twelve days if to be laid on concrete foundation.

The penalty is $4 a day if the work is not completed within the prescribed time. If the delay is more than five days, the engineer may complete the work at the expense of the contractor.

The process of reconstructing an old pavement is very simple. The contractor removes the old pavement and carts the blocks to the proper yard to be sorted. He receives and transports the new blocks to be laid. The old sand is picked and fresh sand added as may be required. The new blocks are placed in position and remain uncovered till inspected and approved by the superintendent or overseer. The joints are then filled full with dry sand by thorough brushing. The whole surface is well pounded with a paving-beetle weighing about 75 pounds. A top layer 1½ inches thick of sand is spread, and by means of water and brooms all joints are carefully filled. This process is continued till water flows over the surface without penetrating any of the joints.

If the pavement is to be laid on a concrete foundation, the earth upon which the foundation is to rest must always be previously pounded, watered, and puddled with care. The city may roll it at its own expense. The contractor lays the concrete foundation as described on page 72. Upon this foundation a 3-inch layer of sand is spread in which the blocks are bedded. The joints are sometimes filled with a fluid mortar of Portland cement and sand instead of simple sand alone.

II. Macadam Pavement.

The area of macadam pavements is 1,724,632 sq. yards.

They are maintained almost entirely by the city directly with the force of the street department, the material only being furnished by contract, delivered either in depots or on the street where required.

The number of men permanently employed is 886, comprising 6 inspectors, 69 foremen, and 811 ordinary roadmen. In addition some 230 assistant roadmen are more or less permanently employed, as occasion requires.

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The cost of construction of a macadam pavement, including all charges for material, labor, rolling, and general expense, was, for the year 1893, $0.80 per square yard where flints only were used, $1.15 where millstone grit and flints were used, and $1.34 where porphyry and flints were used.

The cost of maintenance for the same year was $0.45 per square yard as a general average of all of the macadam pavement. In streets where the travel is heavy the cost would be much greater, and in fact the higher annual cost of maintaining the macadam pavement in proportion to the amount of travel is one principal reason given for the substitution for it of one of the three other kinds of pavement, according to the requirements in each case. In 1893 the sum of about $2,260,000 was appropriated for such change where the annual cost of maintaining the macadam pavement exceeded $0.50 per square yard, and an additional sum of $1,254,000 where the change was made for other reasons.

Under the system of general rechargings, as has already been stated, such repairs as are made during the period between successive rechargings are strictly confined to the filling of holes and the preserving of an even surface of the roadway. In some of this, as well as in other operations, the roadmen work separately, each within his section. Several times a day, according to the weather, they scrape off the soft or fluid mud or sweep off the dust. These scrapings and sweepings are collected in the gutters, and are there washed in a stream of hydrant water in such way that the fine mud is carried into the sewers and the coarser sand is left behind, to be removed for other uses.

The same roadmen are also required to water the streets frequently in dry weather with hose from the hydrants, and on streets where there is much travel to wash them every five or six days with an abundance of water and to thoroughly sweep or scrape them. This washing is always done in the morning, as soon as the travel becomes sufficiently active to loosen the mud and facilitate the sweeping.

The sweeping is done, so far as circumstances admit, by sweeping-machines, each of which, drawn by one horse, is capable of cleaning 5400 square yards an hour, and is equivalent to the work of ten men. One hundred machines are employed on the macadam pavements alone.

III. Asphalt Pavement.

The area of asphalt pavement is about 368,000 square yards.

It was adopted as a substitute for block-stone and macadam, in order to get rid of the noise of the former and of the mud and dust of the latter. It is noiseless and free from mud and dust, and on this account well suited for the immediate vicinity of dwelling-houses, public buildings, schools, hospitals, etc. Its disadvantage, however, is that it becomes slippery during a light rain, and must consequently be kept perfectly clean. When the surface becomes slimy it must be well washed with an abundance of water and lightly sanded. The care of it demands more labor and consequent expense than the care of block-stone pavement. The same is, however, true of wood pavement, the surface of which requires the same care and nearly the same expense.

At one time there was a prejudice against asphalt, for the reason that it softened during hot weather and became disintegrated by severe cold. These defects have been to a large extent corrected by a proper mixture of different asphalt rocks, and also by the adoption of the foundation of cement-concrete.

Asphalt is used not only for the roadways, but, in a somewhat modified form, for the sidewalks; in fact it is the material almost exclusively employed for the latter. Thus the area of asphalt sidewalks is about 4,494,000 square yards out of a total area of 5,289,430 square yards, that is, 85% of all the sidewalk pavement of Paris.

The street-pavement proper is only 402,394 sq. yds., that is, 38% of street pavements of all kinds.

Both sidewalk and street pavements are all, with some unimportant exceptions, built and maintained by contract. The present contract is for five years from March 1894, and gives in detail the requirements as to the quality and character of the materials used, the mode of construction, etc.

The street-pavements are made of the natural asphalt rock alone.

The sidewalks are made of a mixture of the same asphalt rock with natural bitumen and sand.

Asphalt Rock.

The contract calls for the natural asphalt rock which occurs in certain specified localities in Switzerland, Savoy, the Department of Gard in the east of France, and also in Sicily. It must be a homogeneous limestone, of brown color and with a fine grain, having a quite compact texture and be uniformly impregnated with natural mineral bitumen in such way as to show no parts either black or white. It must be entirely free from iron pyrites and contain not more than 2% of clay. All parts of the rock which contain less than 5% of natural bitumen are rejected.

The rock from different localities differs in composition, compactness, and in percentage of bitumen, that generally used containing from 7% to 13%. It is mixed in such proportions as to give the percentage of bitumen desired.

Street Pavement

The contract requires that the ground asphalt rock shall contain at least 6% and at most 13% of its weight of bitumen, the exact amount to be determined in each case. Also, that—

1st. The rocks mixed shall differ only in their percentage of bitumen, and that no part shall contain less than 5%.

2d. The different rocks must be mixed before being ground.

Asphalt obtained from the tearing up of old pave-

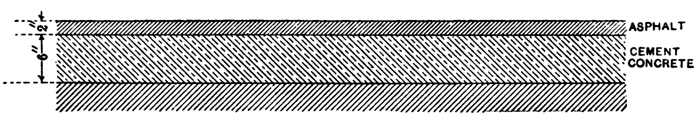

FIG. 12.

ments shall not be mixed with fresh rock or be used at all for this work.

The asphalt rock is ground cold to a powder as fine and homogeneous as possible with the most perfect rolls; this powder must pass through a screen with 1/10-inch mesh. It is then heated in continually revolving cylinders, and kept at a temperature of from

248° F. to 268° F. until all moisture has been evaporated.

The powdered rock, while still hot, is loaded at once into carts, so covered as to prevent as much as possible the escape of heat, and brought promptly to the street where the pavement is being laid.

The 6-inch Portland cement-concrete foundation, such as heretofore described, has already been laid. The asphalt layer, when finished, is generally 2 inches thick.

The powdered rock is quickly spread upon the foundation, as soon as it arrives, levelled with rakes, pounded with heated iron rammers at first carefully and lightly, smoothed with a hot iron tool, pounded again with more force, again smoothed with the hot tool, and pounded a third time thoroughly. The compression is completed by means of a roller weighing not less than 1100 lbs. passed repeatedly over the surface till the layer is quite cold.

The cost of constructing an asphalt pavement, including the 6-inch foundation of Portland cement concrete and a 2-inch layer of compressed asphalt, varies from $2.84 to $3.10 per square yard, the concrete foundation costing 75 to 80 cents, The expenditure in Paris for maintenance and large repairs in 1893 was a general average of 37 cents per square yard.

Sidewalks.

The excellence of the sidewalks of Paris is well known.

The material used for them is known as "bituminous mastic," and is composed of finely powdered asphalt rock mixed hot with a varying proportion of hot bitumen similar to that contained in the natural rock.

The rock is powdered in the manner already described. The contract requires that it be melted and stirred during at least six hours with a quantity of mineral bitumen sufficient to form a mastic which, when cold, will be a homogeneous mass slightly elastic, but not softening at a temperature of 104° F. This mastic while still hot and in a pasty condition is run into moulds, forming cakes that weigh about 56 lbs. It must contain not less than 15% nor more than 18% of bitumen.

There are two qualities of the bituminous covering for sidewalks. The first contains by weight—

Bituminous mastic....................	100 parts
Bitumen for fluxing..................	6 "
Sand	60 "

The second contains—

Bituminous mastic....................	100 parts
Bitumen as flux......................	10 "
Sand.................................	60 "
	170 parts
And an equal quantity of bitumen from old sidewalks, carefully freed from sand or other adherent foreign matter	170 "

When a sidewalk is to be laid, the ground is first thoroughly pounded and puddled while being graded to a slope of 1 in 50 from the inside toward the curb.

Upon this the foundation of hydraulic or Portland cement-concrete, 4 inches thick including a surface coating of 1/3 inch thick of cement, is accurately laid, and allowed to become perfectly dry.

The bituminous covering is then prepared at the furnaces. The mastic is broken into pieces 1/2 in. to 1 in. in diameter, remelted with the 5% or 10% of pure bitumen, and the 60% of sand fine and perfectly dry is added gradually to the mixture in the heated fur-

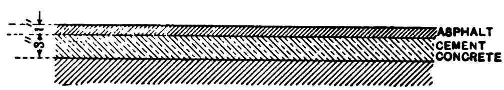

FIG. 13.

nace at intervals during the eight hours of heating and stirring. During this time the mass must be kept at a temperature of not less than 280° F. nor more than 360° F., and be constantly stirred.

This mixture when ready is run hot into heated portable cylinders holding about 1 ton, and carried at once to the point where it is to be used. It is kept always at the same temperature by a small furnace under the cylinder, and is frequently stirred during transit and up to the moment of use.

The bituminous mixture is then spread and, while still hot and plastic, made perfectly even and smooth with wooden tools. A very little dry sand is sprinkled over it, and in twenty minutes the surface becomes quite hard, and can be walked upon.

This bituminous covering is generally 3/5 inch thick.

Bitumen.

The bitumen used is always the natural mineral product derived directly from the asphalt rock or similar sources, and must come from certain specified localities. It must not contain any foreign substance, or water or clay or volatile oils; when heated for 48 hours at a temperature of 230° F. it must not lose more than 3% of its weight. It must be viscous at ordinary temperature, never becoming brittle nor fluid; drawn out into threads it must break only when the thread is very slender.

The bitumen from Trinidad is also used, but owing to the amount, sometimes as much as 33%, of fine clay, sand, and vegetable mixed with it, it must first be thoroughly refined.

Sand.

The sand for this use must be entirely free from earthy and foreign matters, it must be dried and freed by successive screenings of all grains less than 1/12 or more than 1/6 inch in diameter.

IV. Wood Pavement.

Wood pavement was adopted, like asphalt, to secure a less noisy and more even pavement than block stone and macadam.

Its area is somewhat more than 1,000,000 square yards, which is about one tenth of the total pavement of all kinds.

The first wood pavement was laid in 1884 under contracts with certain companies, by the terms of which they were to bear the first cost of it, to maintain it satisfactorily during the eighteen years of the contract, and at the end of the contract to relay it all anew. As compensation they were to receive annually during the eighteen years $0.40½ a square yard of pavement laid as representing the first cost and interest thereon, and in addition thereto as representing maintenance $0.42 to $0.50 a square yard, according to the amount of travel. For the purposes of this calculation the first cost of construction, including also the cost of removing the former pavement, was assumed to be $3.85 per square yard.

At present and for some years past all of the new pavements have been laid by the city directly.

The cost of substituting a wood pavement, including the 6-inch cement-concrete foundation, for block stone and macadam is given as follows:

Kind of Pavement.	Wood Pavement. 6 in. thick. Per sq. yd.	Wood Pavement. 4¾ in. thick. Per sq. yd.	Wood Pavement 4 in. thick. Per sq. yd.
Block-stone....	$3.12½	$2.63	$2.46
Macadam......	3.46	2.90	2.72

The tendency to-day is to substitute, in certain sections of the city, wood and asphalt for block stone and macadam. In general, wood is laid in streets that are broad, open to the sun and air, and where travel is constant. The expectation is that the pavement shall wear out and not perish from decay. The durability of the pine blocks as originally laid is from eight to nine years upon the boulevards and main streets, where the travel is constant and heavy. The blocks are often worn down in such places to one half of their original depth. The pavement of the Place de la Concorde, for instance, was renewed in March 1895. It was laid in September 1885. Had all of the blocks been homogeneous the pavement would have lasted much longer. The failure of isolated blocks made the pavement uneven before it was worn down to the extreme limit.

The wood pavement of the Place Vendôme was renewed in May 1895, after seven years' wear.

The statement of the annual wear of the following streets is from official sources:

	Decimals of 1 Inch.
Boulevard des Poissonniers / " " Italiens	0.2908
Rue de Rivoli	0.1968
Avenue de l'Opéra	0.1572
Rue de Castiglione	0.1257
" " Londres	0.1100
Avenue d'Antin	0.1060
Place de l'Alma	0.0943
Rue de la Chaussée d'Antin	0.0864
Rue de Rome	0.0746

The wood is used in its natural state, no treatment by any antiseptic agent to prevent decay being made. The blocks, it is true, are dipped in creosote, but this is simply to protect them slightly while they are stored in the yard awaiting use. It is of no value after they are once laid.

All of the wooden pavements to-day in Paris are laid upon a foundation of Portland cement-concrete 6

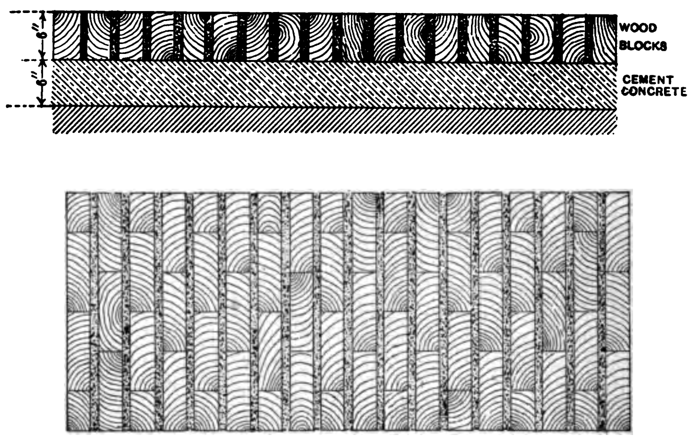

FIG. 14.

inches thick, the surface of which is made perfectly smooth. The wooden blocks have in general a depth of 6 inches and an exposed surface of 9 × 3⅛ inches. They are placed in rows, with a space of 7/16 inch between two successive rows, and the blocks arranged so as to break joints. Experiments have been tried of making the spacing between the rows 1/4 inch, and even 1/8 inch only, in order to secure greater solidity, but the results are not stated.

The actual laying is very simple and rapid. The blocks are placed on their edges within easy reach of the pavior, who with a hatchet quickly lays each block in its proper place in the row, spacing the rows as he goes on by strips of wood of the required thickness and 1½ to 2 inches broad and 5 or more feet long. These he lays in obliquely with their ends projecting above the surface, so that they may be readily withdrawn when some half-dozen rows have been laid, and used again as the work proceeds.

As soon as they are withdrawn hot coal-tar is poured into the spaces between the rows so as to fill about 1 inch of the 6 inches of depth. This is done in order to hold the blocks more firmly in place during the subsequent operations, and not as a preservative of the wood.

The 5 inches remaining of the 6 inches of depth are at once filled carefully with a fluid mixture of cement and sand in the proportion of 750 to 850 lbs. of Portland cement to each cubic yard of sand.

The surface of the pavement is then covered with a thin layer of coarse gravel, the hardest and sharpest preferred, in order that, under ordinary travel, the hard particles may be ground into the fibres of the wood and make the surface harder and less slippery. They penetrate the wood to the depth of one fourth of an inch or more, and materially increase the durability of the pavement as well as its impermeability to water.

When the pavement is first laid and when first wet the wood swells, and the expansion manifests itself in a lateral pressure, which is provided for near the curbstone on each side of the street by leaving a free space of 2 inches between the pavement and the curb, which space is later filled with sand as required.

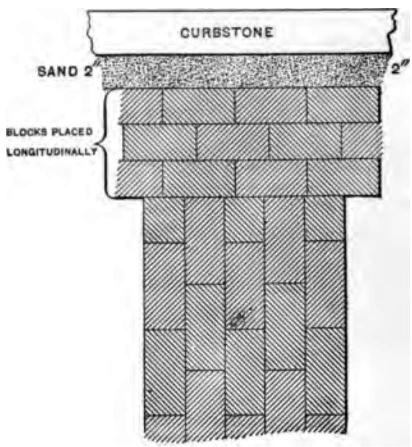

FIG. 15.—Plan.

Kinds of Wood.

The wood first used was Norway spruce or fir. Later the more or less resinous pine from the *Landes*, South of France, has been much used, and with better results. The pitch-pine from Florida is considered more durable than the latter, and is used to a limited extent. Within the last three or four years experiments have been made with the "Jarrah" and "Karri" woods from Australia, the "Teak" from Java, the so-called "Bois de fer" from Borneo, and the "Liem," from Annam—all of them much harder and more compact than the woods heretofore used. It is too soon to expect conclusive results, but it is believed from the observations already made that one or other of these woods, or one equally hard and homogeneous, will prove more economical on streets where the wear is greatest than any of the woods heretofore used. Great care is taken that, whatever be the wood, the blocks laid in any one street shall be as nearly homogeneous as a strict selection can insure. Could they all be absolutely homogeneous, the wear would be uniform and the formation of holes due to the decay or giving way of isolated blocks be prevented. It would greatly lengthen the life of a pavement.

As has been already stated, the standard depth of the blocks, that is, the thickness of the pavement, is 6 inches; but on several streets it has been reduced to $4\frac{3}{4}$ inches, and even to 4 inches. A thickness of $4\frac{3}{4}$ inches is apparently quite sufficient in streets where the travel is moderate and where repairs become necessary, not from wear, but because of the holes due to the decay of isolated blocks.

When a pavement must be entirely renewed, in consequence of wear rather than of decay, a certain number of the blocks taken up may still be perfectly sound and comparatively little worn. In order to utilize what value these may still have, they are carted to the yard of the street department and cleaned. Then by means of a circular saw the worn part of each block is cut off evenly, reducing the height of the block to 4¾, 4, or even 3 inches. The several sizes are piled, to be used again on streets where the travel is light.

If the trials of the imported hard woods prove as successful as anticipated, the use of them will doubtless be increased, even at the relatively high cost. To bring the cost within satisfactory limits the thickness of the pavement may be made, say, 4 inches instead of 6 inches.

Cost of Construction and Maintenance.

Pavement.	Construction Cost per square yard.	Annual Maintenance per square yard.
Block-stone	$2.81 to $3.85	$0.14
Macadam..........	0.80 " 1.34	0.44
Asphalt.............	2.84 " 3.10	0.37
Wood............	3.00	0.46

The above figures are for the year 1893, as appears by official report.*

Width and Convexity.

Experience has shown that the different conditions to be satisfied are nearly realized by giving the road-

* Notes à l'appui du Compte des Dépenses de l'Exercise 1893. Monsieur L. Boreux, l'Ingénieur en chef de la Voie publique.

way such a convexity that the cross profile of the surface is parabolic.

From the following table will be seen the proportion of roadway and sidewalk in streets of certain standard widths, as well as the convexity usually adopted.

Total Width of Street.	Width of Roadway between Curbstones.	Height of Centre of Roadway above the Bottom of Gutters.	Convexity Relation of the Height of the Centre to whole Width of Roadway.	Width of each Sidewalk.
Feet.	Feet.	Feet.	Feet.	Feet.
32.8 (10 met.)...........	21.64	0.383	1/57	5.58
39.36 (12 met.)..........	23.61	0.410	1/57	7.87
49.2 (15 met.)...........	29.52	0.498	1/59	9.84
65.6 (20 met.)...........	39.36	0.642	1/61	13.12
Boulevards and Avenues	45.92	0.741	1/62	
	52.48	0.839	1/62	
Exceptional Streets......	59.04	0.938	1/63	
	65.60	1.036	1/63	
	88.56	1.377	1/64	

Cleaning and Watering.

Cleaning comprises three general divisions:

1. The removal of mud and household refuse, which is done by contract.

2. Sweeping and watering, which is done exclusively by the street department, except that sand is furnished by contract as well as the use of some of the sweeping-machines.

3. The removal of snow and ice.

The surface (streets and sidewalks) cleaned is about 18,894,000 square yards. The total expense for the year 1893 was $1,850,611, which is a general average of nearly 10 cents a square yard.

The removal of mud and of household refuse is made between 6.30 and 8.30 A.M. from April 1 to October 1, and between 7 and 9 A.M. from October 1 to April 1. Each house-owner is required by law to furnish from 9 P.M. for the several tenants one or more receptacles for refuse which are to be brought out each morning onto the street in front of the house one hour at least before the carts come by; as soon as emptied they are taken into the house.

The contractors furnish their own carts for the removal of this refuse, and become the owners of it. They generally sell it to farmers or kitchen-gardeners as manure.

This refuse is said to be a good fertilizer, nearly equal to farm-yard manure, as appears by the following analysis:

	Percentage.
Nitrogen	0.38
Phosphoric acid	0.41
Potash	0.42
Lime	2.57

The city nevertheless has difficulty in disposing of this refuse, due mainly to the objections on the part of adjacent villages to the use of it within their territories or to the carting of it through them. Arrangements have consequently been made with all the principal railways radiating from the city for transporting it at a reduced tariff to more or less remote points. The total amount of refuse removed in the year 1893 was 1,050,000 "tonnes;" of which 680,000 tonnes were utilized in the immediate vicinity, 100,000 tonnes transported on the river to distances from 6 to 37 miles, and 270,000 tonnes transported by railway.

The market value of the fresh refuse varied in 1893 from 12½ to 25 cents a cubic yard, taken on the cart or boat.

The total expense of the removal of all kinds of refuse, including the street sweepings that are not washed into the sewers, was, in 1893, $377,186.

Each of the twenty wards is made the subject of a separate contract for a period of five years, and no one contractor is awarded more than four of these contracts. The contractor furnishes the cart, horse, and driver. The city furnishes a street-sweeper to assist in loading, a woman to sweep up whatever may have fallen when the refuse barrels are emptied into the cart, and a rag-picker, who remains in the cart and assists.

The expenses attending this method of disposing of the refuse at more or less remote points—and these expenses under the new contracts are 23 per cent greater than under the former contracts—have led the engineers to study more carefully the methods pursued elsewhere, notably in England. Within the last two years a furnace has been built by the city for burning a certain amount of the refuse, and although the results are understood to be satisfactory, the question is not considered settled, as experiments are still going on.

Street Sweeping.

The sweeping of the streets is done by hand or by sweeping-machines.

The force engaged comprises—

		Yearly Pay.
37	inspectors............ ...	$360 to 396
131	foremen................	336 " 348
612	roadmen....	324
1383	laborers....................	300 " 324
951	women sweepers........ .	192 " 216
408	rag-pickers, paid 24 cents a day for about three hours' labor.	
3522		

The women sweepers are required to work only seven hours a day. The rag-pickers are occupied only while the carts are collecting and removing the household refuse. They keep whatever of value they find, which is estimated to be about twenty cents a day. The others are required to work ten hours a day.

The prescribed routine of service is as follows:

4 to 6.30 A.M.—Sweeping and washing of the sidewalks and the streets; sprinkling of sand where required; general cleaning of the urinals.

6.30 to 8.30 A.M.—Removal of the household refuse and the street sweepings; continuation of the above work.

8.30 to 11 A.M.—Picking up horse-droppings; washing of the gutters; watering of the streets by watering carts and hydrant hose; thorough cleaning and disinfecting of the urinals. End of the day for the women sweepers.

11 A.M. to 1 P.M., dinner.—If circumstances require it, a part of the force continue work and dine later.

1 to 4 P.M. (end of the day).—Sweeping by the machines; watering; picking up horse-droppings; sweeping of sidewalks; thorough cleaning and disinfecting of the urinals; washing of benches, etc.

4 to 7 P.M.—Extra service with extra pay, when necessary for sweeping, watering, washing gutters, or spreading sand.

7 to 9 P.M.—During five months of winter spreading sand on the asphalt and wood pavements.

When the streets are swept during a dry season they are first watered to avoid dust. When the surface is muddy, it is well watered in order to loosen the mud. During a rainy time the sweeping-machines are passed several times in succession over the surface to clean it and remove the puddles of water. When the asphalt or wood pavement is not muddy, it is dried by the rubber scraper. The dry sweepings are removed in carts. The semi-fluid ones are washed in the gutter in a stream of hydrant water and the fine particles carried into the sewer. The coarse sand is reserved to be used elsewhere, or carted away.

A conspicuous feature is the great abundance of water used to keep the streets clean. The water of the Seine is pumped into reservoirs and is used for this and all other purposes except drinking.

During hot or dry weather the streets are thoroughly washed clean—

Block-stone and macadam pavements every three days;

Asphalt pavements every two days;

Wood pavements every day.

In general this washing is done between 4 and 8 o'clock in the morning. The gutters are washed twice a day, and the pavements are sanded as often as necessary to prevent their becoming slippery.

The city owns 394 sweeping-machines, 100 of which are assigned to the care of the macadam pavements, 234 to general cleaning, and 60 kept in reserve for special service.

The cleaning of the sidewalks is done entirely by hand.

Watering.

The watering of streets is done wholly by the roadmen engaged in cleaning and by those in charge of the macadam pavements, and either by means of watering-carts or hydrant hose. Formerly it was done by watering carts only, but at present the latter method